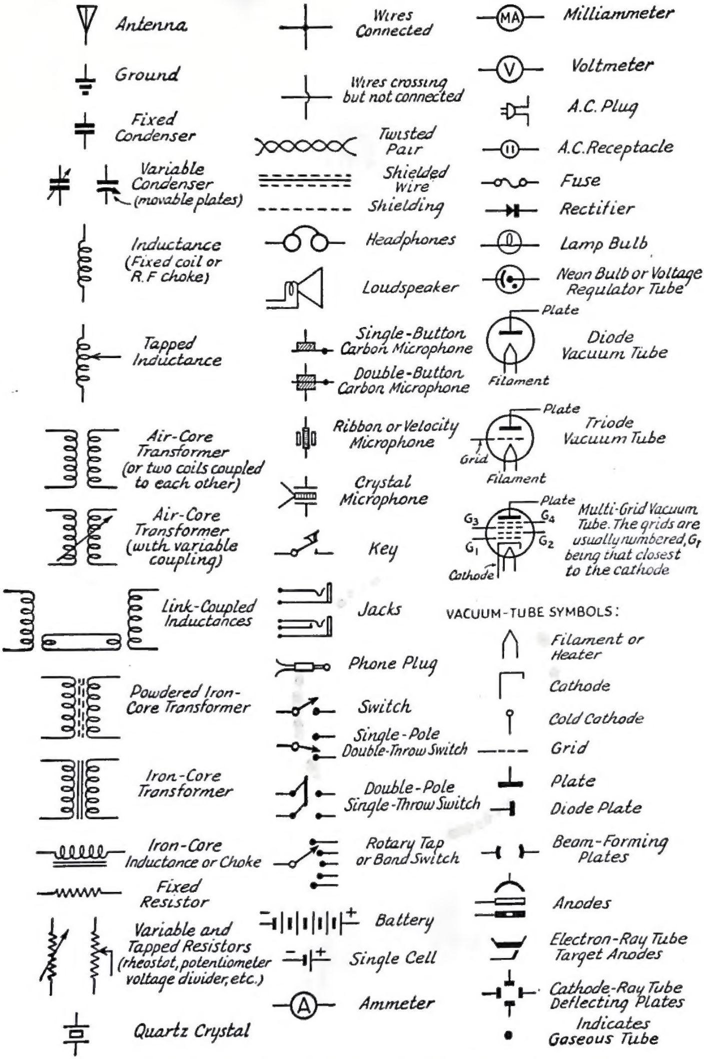
SIMPLE RECEIVERS AND TRANSMITTERS

25¢

# HOW TO BECOME A RADIO AMATEUR

*With Complete Constructional Details of A Simple and Inexpensive Amateur Station*

Published by the AMERICAN RADIO RELAY LEAGUE, West Hartford 7, Connecticut




SCHEMATIC SYMBOLS USED IN CIRCUIT DIAGRAMS

James E. Lewis 112 YF 54
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New Kensington, Penna.

# How To Become A Radio Amateur

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You are interested in radio. You know that there are people called "radio amateurs" who talk amongst themselves at all hours of the day and night. You may have heard them at certain settings on the dial of your all-wave receiver; you may have read of them in your daily newspaper after some flood or other emergency in which they rendered great public service.

You would like to know how these people came to be amateurs, how they acquired the ability and the equipment to get on the air and talk. You might like to become an amateur yourself — at least you would like to know how to go about becoming one.

The purpose of this booklet is to tell you, as simply and straightforwardly as possible, what amateur radio is, how one can become an amateur, how to build a simple receiver and transmitter, and how to get on the air.

### A Universal Hobby

What *is* amateur radio?

Amateur radio is direct private experimental communication, from your own home, on apparatus you have usually built yourself, with other amateurs similarly equipped.

Anyone can become an amateur — boy or girl, man or woman — almost regardless of previous training and experience. All that is required is a sincere desire to learn and a little effort acquiring the necessary knowledge. Boys of 10 and 12 have become amateurs — as have men of sixty. They come from all walks of life, their sole bond the fascination that the amateur game affords.

You may already know the thrill that comes from tuning in some distant station in a foreign land on an all-wave receiver. But that is only a small part of the thrill that comes only to the radio amateur — the thrill not only of hearing foreign countries but also of throwing the switch on his own transmitter and talking with the stations he hears.

### Adventure!

Each night's operation is a new adventure into space. An amateur's station — sometimes an elaborate affair that rivals the equipment of a big broadcasting station, more often an inexpensive outfit assembled at home in spare moments — becomes a modern Aladdin's lamp. You never know, when you sit down to your transmitter and receiver for a few hours' operation at the end of the day's work, what those hours will bring. Perhaps, to start, a few friendly chats with neighboring amateurs in nearby states. Some of these may be contacted for the first time that particular night; others may be amateurs who have been "worked" before and with whom regular schedules have been arranged once or twice a week. Following this there may be an opportunity to pass the time of day with a Virgin Islander or, later, a missionary afar in Africa or a weather observer on some faraway U. S. island in the Pacific. You may suddenly be asked to relay a message for assistance for a town even then being devastated by a hurricane, or have the experience, as many amateurs have, of exchanging signals with some far-off Arctic or Antarctic expedition.

### Endless Variety

These are but a very few of the things that you, as an amateur, may do. The reason that amateur radio is often called the most satisfying and thrilling of all hobbies is that it offers something for everyone. It is, to use a familiar phrase, "all things to all men."

For example: You may be a "tinkerer" — you may like to play around with gadgets, build them up, make them work. Amateur radio is the ideal hobby for the tinkerer who likes to go into the "why" of the things he builds. It offers endless room for experiment, an infinite variety of problems to overcome. You may be a "rag-chewer." The most enjoyment you know may come from getting together with a crowd of good fellows and talking over everything under the sun. Amateur radio is full of confirmed addicts of the conversational art; indeed, there is even a "Rag-Chewer's Club," with a membership certificate signed by "The Old Sock" himself, for those who can qualify.

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#### Competition

You may have the competitive urge. If your biggest kick in life comes from putting everything you've got into some sport or game that requires a high order of intelligence and skill, amateur radio will provide plenty of activities to test your mettle. Every day in the year thousands of amateurs compete to see who can relay the most messages; elaborate traffic nets, with trunk lines, field officials and comprehensive organization have been established by the Communications Department of the American Radio Relay League. Hundreds of other amateurs compete with each other in working DX (distant) stations. DXing is actually a glorified form of fishing; it takes endless patience and skill, but to the true "fisherman" it has a zest nothing else in the world can equal — and it's a sport you can indulge in any day, any season of the year.

Beyond these daily activities there are dozens of contests of various kinds held annually. The biggest is the Sweepstakes, engaged in by amateurs all over the United States. Field Day brings thousands of amateurs into the countryside with portable self-powered equipment. In these, as in the smaller contests, amateurs compete not only on a national scale but locally.

But all this still does not convey the whole picture of amateur radio. If one is interested in Army or Navy activity he will find himself freely encouraged to join either the communications reserve of the U. S. Navy or the Army-Amateur Radio System, each of which conducts weekly "drills" over the air to train operators in the intricacies of military radio procedure. In the comprehensive field organization of the ARRL you may find satisfaction in an appointment as Official Observer, as a sort of voluntary policeman of the air, or as an Official Broadcasting Station, transmitting the latest amateur news bulletins on regular schedules, or as an Official Experimental Station, helping solve the mysteries of the ultrahigh frequencies.

Nor is all of amateur radio confined to contacts over the air or solitary experimentation. There are nearly 400 active radio clubs in the country affiliated with the ARRL, and they offer programs of wide general interest. Each year about twenty divisional conventions and several hundred "hamfests" are held. Hundreds of amateurs attend these fraternal get-togethers, which last from an afternoon or evening to as much as three days. Not only are they instructive, not only do they permit amateurs to meet in person those they have talked with over the air, but they are mighty good fun, as well.

#### From Champions to Newsboys

This, then, is amateur radio. That its appeal is universal is demonstrated by the type of people that pursue it. A cross-section of amateur radio is a cross-section of any community. The popular myth that all amateurs are short-trousered "attic experimenters" has no basis in fact. It is true, of course, that a considerable number of boys and girls under 20 do become amateurs, for it is one of the advantages of amateur radio that it is not too intricate or abstruse for young people of high school age to master. But if you, as an amateur, get on the air tonight or tomorrow night and contact other amateur stations you may find yourself talking with the president of a stock exchange or a Davis Cup tennis star or a famous radio comedian or a foreign Prince — or your newsboy or filling-station owner. . . . The list could go on endlessly, but the point is that amateur radio is indeed a universal hobby, having an appeal to professional worker and artisan alike, to young as well as old.

Amateur radio is not a spontaneous development. It is the result of four decades of evolution. For over 30 years it has been guided in technical and operating progress, and defended against legislative threat, by its national organization, the American Radio Relay League.

The League, which was founded in 1914, is the spokesman for amateur radio. Numbering in its ranks a majority of the active licensed amateurs, it is operated as a a mutual non-stock corporation, entirely amateur-owned and directed. Through a representative system of government, it makes the amateur body articulate in representation at Washington and at international radio conferences. Scores of times it has averted the threatened abolition of amateur work. From its headquarters at West Hartford, Conn. — where visitors are always welcome — where fifty people are employed, it publishes the monthly journal of amateur radio, *QST*, as well as many amateur handbooks and booklets, all available at low cost to help amateurs obtain the greatest enjoyment from their hobby.

#### Licenses Essential

It is the law that no one can operate a radio transmitter without a license from the United States Government. All forms of radio are administered by a government agency at Washington called the Federal Communications Commission. The Commission assigns radio facilities to all types of radio stations — and often certain services feel that they require more space on the air. This competition, the necessity for every class of radio station to demonstrate that it is operated in the maximum of public interest, convenience and necessity, forces amateur radio — through the ARRL — to maintain a united front in order to preserve its rights.

The FCC requires that every amateur station and operator be licensed. There are heavy penalties for operation of an unlicensed station — a maximum of two years in jail and a fine of $10,000. It is the purpose of this booklet to show

how the necessary licenses can be acquired and the other requirements met.

#### The Three Steps

There are three steps involved in the process of becoming an amateur. The first consists of learning something about radio; assembling a station — receiver, transmitter and antenna — and learning the code. The second step consists of acquiring a knowledge of amateur operating practices, customs, etc. The third is the acquiring of the government station and operator licenses which every amateur must have before his *transmitter* can be operated and, in connection with this step, the study of a small amount of basic radio theory and radio regulations to enable the applicant to pass the examination given every amateur.

The first two of these steps are covered completely in the pages of this booklet. Learning the code requires only a relatively small amount of application and mental effort, and thousands of amateurs have learned the code in the time-honored fashion we describe here. The rudiments of amateur customs and practices, operating procedure, etc., are given for your information. Detailed treatment of the third step is beyond the scope of this booklet; to cover licensing procedure and examination preparation thoroughly would perhaps double the size of this booklet. But manuals and texts are available on these subjects, and later on we will tell you what they are and where they may be obtained.

#### To Build or Buy?

Should you build your own receiver and transmitter, or should you buy one of the manufactured units now available? Every beginning amateur has faced that question. Despite the possible temptation to buy ready-made equipment, we strongly urge that you build at least your first transmitter and receiver — even though you can afford to buy the best on the market. Only by actually building and testing radio apparatus can you acquire the thorough understanding of radio that every good radio amateur should have. All the theory in the world cannot take the place of practical experience — and the only way to gain experience is to do the thing yourself. So build your own, at least at the start.

## HOW RADIO WORKS

The radio amateur must have a reasonably good general knowledge of radio principles, not only to successfully build and operate his equipment, but to pass the Federal license examination. This does not mean that an engineering training in the subject is required; it does mean, however, that some time and application in acquiring an understanding of basic principles will be required.

The study of a standard radio text is recommended. The brief explanations which follow are intended to serve only as a preliminary to such study, particularly for the benefit of those without previous knowledge of radio or electricity.

You have heard of *molecules*, as the smallest units to which any substance — wood, metal, water — can be broken down. These molecules are made up of various combinations of *atoms*, which are the basic chemical elements. Every substance known is made up of various combinations of these atoms of which there are more than 90 varieties.

When we try to go inside the atom, in order to learn what it is made of, we leave the field of solid *physical* matter and must think in terms of *force*. For atoms are made up of *electrons*, and electrons, as you might guess from their name, are nothing more or less than electrical charges — little bits or particles of energy or force. Each atom contains a number of these electrons, together with a *nucleus;* the electrons are believed to rotate about the nucleus much like the planets about the sun. The nucleus, in turn, is made up largely of *protons* and *neutrons*. The protons are the opposite of electrons; they have a *positive* charge, while the electrons have a *negative* charge. There is also a large difference in the mass of the two — the proton being about 1860 times heavier than the electron. The neutron has the same mass as the proton but has no charge.

#### The Electric Current

You know that when two permanent magnets are placed together with the north and south poles facing they exert a mutual attraction. Similarly, the positively-charged nucleus attracts the negatively-charged electrons; in many substances the attraction is so great that the electrons are rigidly held and can escape only with great difficulty. In other substances, however, the electrons are not so strongly attracted, and it is quite easy to dislodge them. If an electron is dislodged from an atom in such a substance, this atom in turn attracts a new electron from a neighbor, and the neighbor from its neighbor down the line, and so a regular chain of motion is set up. This motion of the electrons is called *electric current*, and it is the basis of all electricity and all radio theory.

The careful reader will have noticed that only in some substances was it said that this movement of electrons is easy. Such substances are known as *conductors*, because they conduct electric currents quite readily. They include most of the metals, especially silver, copper, aluminum and steel (listed in the order of their *conductivity*).

Other substances have electrons so firmly fixed in their atoms that they are dislodged only with great difficulty, and little or no electric current

can flow. Such materials are known as *dielectrics* or *insulators*, meaning that they can be used to insulate electric currents when placed between the conductors of those currents. Bakelite, porcelain and other ceramics, wood, rubber, air — these are good insulators.

### Resistance

This characteristic of nonconductivity is described as *resistance* — actually, the resistance of the electrons to being dislodged from the atoms. Certain metals have a relatively high resistance; a small amount of current can be made to flow in some nonmetals, on the other hand, and they are therefore not regarded as good insulators.

In trying to force movement of electrons, or current flow, in poorly conductive wire the energy used to overcome the resistance of the wire is dissipated or used up in the form of heat. Examples of this are such electric appliances as toasters, stoves, etc., where the heat generated by forcing electricity through high-resistance wire is put to use. In the case of an electric light bulb, on the other hand, not only is heat generated but the wire glows from the heat, like a piece of red-hot metal in a fire, and thus creates light.

The measure of the resistance in any given piece of wire is stated in *ohms*. This is a term derived from the name of the man who first found that the resistance of a piece of wire was constant regardless of the amount of current flowing through it, and who, on this fact, established what is known as *Ohm's Law*. This is the basic law in electricity. It states that *one ohm is the resistance through which one ampere of current will pass at a pressure of one volt.* From the way the statement is made it should be easy to guess that an *ampere* is the measure of the quantity or amount of electric current (like gallons of water per minute), while the *volt* is the measure of pressure.

Remember this expression of Ohm's Law. You will use it innumerable times in your radio career. Expressed as a formula, using the standard symbols of $I$ for current, $E$ for volts and $R$ for resistance, it reads:

$$I = \frac{E}{R}$$

So far we have considered only one kind of electric current — *direct current*, or *d.c.*, flowing continuously in one direction: from negative to positive.

There is another kind of current, known as *alternating current*, or *a.c.*, in which the direction of the current reverses periodically. At one instant this current flows in one direction, at another instant in the opposite direction. Each such complete set of changes is called a *cycle*. The rate at which these changes occur is known as the *frequency* of the current. The polarity of ordinary house-lighting current reverses 120 times each second; its frequency is, therefore, 60 cycles per second.

Alternating current obeys laws similar to those of direct current. It is measured in amperes and volts. Although the actual current and voltage at any instant may vary from zero to maximum, the *effective* values approximate the values for d.c. supplying equivalent power. These effective values are considered to be approximately 0.7 times the maximum, or *peak*, values.

### Inductance

In the case of d.c., the flow of current is limited only by the resistance of the conductor. With a.c., however, the problem becomes more complicated. First of all, let us consider *electromagnetism*. When a current flows through a coil of wire, lines of magnetic force, similar to those in a permanent magnet, are set up by each turn of wire. All of these lines of force together are called the *magnetic field*. However, we are not so much interested in the magnetic qualities of the coil as in their effect on the coil itself.

The lines of force created by each turn of wire also cut across other turns in the coil. In doing so they transfer energy to these other turns, setting up additional current; this is called *induced* current. The induced current flows in the opposite direction to the original current, building up a back pressure opposing the current flow. The more turns in the coil, the greater this induced current — the greater the *inductance* of the coil. It happens that coils are measured by their inductance; the unit of measurement is the *henry*, commonly reduced to millihenries or mh. (thousandths of a henry) and microhenries or $\mu$h. (millionths).

In the case of d.c., the induced current exists for only a brief moment while the magnetic field is building up; thereafter, the current flow is limited only by the resistance of the wire. With a.c., however, the magnetic field builds up and collapses with each alternation. This sets up an intermittent retarding action which serves to limit the flow of a.c. by the average net value of the induced current. In other words, still more resistance to current flow, in addition to the resistance of the wire, has been introduced; this special kind of resistance is called *reactance*. It affects only a.c. It is measured in ohms. The greater the inductance of a coil the higher the reactance — *inductive reactance*, that is, because it is an effect of the inductance of the coil. Inductive reactance increases in direct proportion to the frequency of the current, in contrast to inductance, which does not change with frequency.

Now, having shown what happens in one coil, suppose we put two coils side by side. If current is passed in one, the magnetic field set up in it also cuts across the other. Induced current is set up in the second coil, as well. If suitable conditions exist, practically all the power in the first coil can be transferred to the second — the voltage and

current relationships being in ratio to the number of turns in each coil. This *coupling* or transfer of power is called *transformer* action.

**Capacity**

If a.c. cannot flow through a coil as readily as does d.c., it can apparently flow through an insulator where d.c. cannot. If two conducting plates are placed adjacent with an insulator between them and current is generated or set in motion along a wire connecting the two plates, electrons will pile up on the "negative" plate. This will continue until the pressure of the piled-up electrons equals the voltage pressure from the current generating source. The condenser is then said to have an *electrostatic charge;* the extent of the charge, or the number of electrons which can be accumulated on the plate before a given voltage is reached, is determined by the *capacity* of the condenser. Like the inductance of a coil, it does not change with frequency. Capacity is measured in *farads;* this unit is so large that microfarads or $\mu$fd. (millionths of farads) and even micromicrofarads ($\mu\mu$fd.) are customarily used.

So far, in considering capacity, only the effect of d.c. in charging the condenser has been shown. With a.c., the reversal of polarity causes the charge to build up and collapse with the frequency of the current. This rapidly changing charging current is actually the equivalent of an alternating current through the condenser. Of course, condensers do not permit alternating currents to flow through them with perfect ease. They impede an alternating current just as an inductance does. This effect is known as *capacitive reactance,* and it is the opposite of inductive reactance. It decreases with frequency, and is *inversely proportional* to frequency and capacity.

**Resonance and Tuning**

We come now to a very interesting phase of the subject — *resonance.* It is resonance which enables *tuning* — the ability to select only one radio station from all those on the air.

It was said that reactance changes with frequency — inductive reactance going up in value, capacitive reactance down, with increased frequency. With a given value of capacity, therefore, there is only one value of inductance that will have the same value of reactance as the condenser at a given frequency. Now it happens that the two kinds of reactance are opposite in their effect upon current flow. If a coil and a condenser of equal reactance are connected in series with an alternating current source, therefore, the two reactances, being opposite in their effect, cancel out — and the only resistance limiting current flow is that of the wire.

This is true at only one frequency, however, since the reactances change with frequency and in opposite directions. Thus that particular coil and condenser combination is *resonant* — a *tuned circuit* — at that one frequency. If the frequency is changed the current flow is again limited by the reactance, and the circuit will therefore discriminate against all other frequencies. The "sharpness of resonance" — the degree of selection between the resonant frequency and adjacent frequencies — depends largely on the ratio of the reactance to the a.c. resistance of the coil.

All of the electrical principles discussed so far are involved in the operation of radio equipment.

There is, first of all, the identification of "radio" with "alternating current." The a.c. used as an example in explaining electrical theory had a frequency of 60 cycles per second — ordinary commercial house-lighting current. In some localities a frequency of 25 cycles is used for such current. Getting away from power, if we change sound waves in the audible range into electrical pulses we have a.c. ranging from perhaps 20 to 16,000 c.p.s.

**Radiation**

At about this point (16,000 c.p.s.) it no longer becomes necessary to send current over a wire; instead, it can be sent through space in the form of *electromagnetic radiation.* Just what this is and how it works no one fully knows. It is sometimes explained as vibrations in a mysterious substance called the "ether," akin to sound waves in air. You might like to think of it as an enormous magnetic field.

Anyway, if a piece of wire — an antenna — is supplied with a.c. power of sufficiently high frequency, it will radiate that energy into space. It will travel at a rate of something like 186,000 miles per second until it has all been dissipated. It is convenient to visualize this energy as traveling in waves, and since the velocity can be assumed constant, the "wavelength" is the reciprocal of the frequency. In other words, radiated *radio-frequency* or *r.f.* energy (as it is termed to distinguish it from ordinary a.c. in wires) of 1,000,000 cycles per second (ordinarily described as 1000 *kilocycles* or kc., *kilo* meaning thousand) will have a wavelength of 300 meters (it being the habit to describe wavelengths in meters rather than feet). This is found by dividing 1,000,000 into 300,000,000 (the latter figure being the velocity in meters per second equivalent to 186,000 miles per second).

The energy thus sent forth will, generally speaking, radiate in all directions from a simple antenna wire. Some of it will go along the ground, until it is dissipated, intercepting all receiving antennas in its path and inducing small bits of energy in each. This is the *ground wave.* Most of it will go off into space. This is the *sky wave.* With short wavelengths, this r.f. energy is often *reflected* by an ionized layer of air in the upper atmosphere called the *ionosphere.* It thus comes back to earth at great distances, affording the

extraordinary ability of the short waves to cover the world with little power.

More on the ionosphere later. We turn now to methods of generating and receiving this r.f. energy we have been talking about.

### Vacuum Tubes

The heart of all modern radio-frequency generating and receiving systems is the *vacuum tube.*

We have previously discussed the effect of passing an electric current through the wire, or *filament*, in an ordinary light bulb; the resistance or friction of the wire causes it to *incandesce*, generating heat and light. It also does something more. When the filament is sufficiently heated the electrons not only vibrate furiously in the wire but even leave it. They then cluster around the outside in what is known as a *space charge.*

Now if a *plate* of metal which is given a positive charge from a battery or other electrical source is placed in the evacuated bulb, the electrons in the space charge will stream toward this plate, the vacuum offering little resistance to their flow. This flow is actually an electric current — more specifically referred to as an *electronic* current because it is not in a wire — but it will flow only in one direction: from filament to plate. If a.c. is placed on the plate, therefore, current will flow only during that half of the cycle when the plate is positive. This is called *rectification* — the process of changing a.c. into pulsating d.c. by means of a rectifier tube.

This characteristic of rectification may be used in several ways in radio work. First of all, it may be used to change the 60-cycle a.c. from the power lines into d.c. The d.c. that comes from the rectifier tube will be pulsating, rising and falling with each cycle, but it can be smoothed out by running it through a *filter* — a combination of inductance and capacity which levels off the hills and fills in the valleys.

### Detection

*Detection* is the most important use of this rectification characteristic. It is also called *demodulation.* It consists of taking the r.f. signal that comes in over the receiving antenna and changing it into either the audible dots and dashes of the telegraph code, the audio frequencies of the human voice, the multitudinous pulses of a television picture, etc.

Thus far we have been talking of a vacuum tube with only two elements or *electrodes*, plate and cathode. (The cathode is the filament in certain tubes; in others it is a metal sleeve coated with electron-emitting material which is indirectly heated by the filament.) This type is called a *diode.* There are other types which not only rectify but *amplify*, as well.

These more complex types include an additional element or electrode called a *grid.* It consists of a mesh of fine wires placed between the cathode and plate. In effect, the grid is a valve, controlling the flow of electrons. If it is given a positive charge, it accelerates the flow and more electrons go to the plate — the *plate current* increases. If the grid is given a negative charge. however, this discourages the electron flow and limits the plate current. If it is sufficiently negative practically all current flow is stopped; this is called *cut-off.*

### Amplification

Now, suppose we have a positive d.c. voltage on the plate of a tube. This causes a continuous d.c. flow. Then, suppose we put a negative d.c. voltage on the grid. A certain value of grid voltage will serve to cancel the influence of positive plate voltage, causing cut-off. Since the grid is nearest the filament, the voltage required on it will be smaller than that on the plate. The ratio between the grid and plate voltages required to produce the same effect on the plate current is called the *amplification factor.*

Suppose, further, that instead of having d.c. on the grid we have a.c. As the grid voltage changes through each cycle the plate current changes simultaneously. Now, if the plate current is taken through a resistance or a reactance, this plate current variation will set up a corresponding a.c. voltage — a voltage greater than the grid voltage by the amplification factor of the tube. Thus, where we have an a.c. grid voltage of perhaps 1 volt, we end up with a corresponding a.c. voltage in the plate circuit of perhaps 10 volts. The signal has been amplified 10 times. This may be done either at r.f. — before detection — or at a.f., after.

It is by this means that the microscopic power of a radio signal in a receiving antenna — less than a billionth of a watt — can be built up to the 5 watts or more of power delivered to the average loudspeaker.

A tube having three elements — cathode, grid, plate — is called a *triode.* There are tubes called *tetrodes* in which a *screen-grid* (sometimes called an accelerator grid) is inserted between grid and plate as an electrostatic screen. This greatly increases the amplification factor. *Beam* tubes also have four elements, in which the fourth electrode is used to concentrate the electron flow to the plate for maximum efficiency. *Pentodes* are tetrodes with still another grid, located between screen and plate. This third grid is called the *suppressor grid;* operated at cathode potential, or voltage, it further improves tube performance by preventing electrons from bouncing back to the earlier grids from the plate.

### Oscillation

The generation of radio-frequency power is also accomplished by the vacuum tube, and it also utilizes this characteristic of amplification. Sup-

pose that in the amplifier discussed above 1/10 of the 10 volts in the plate circuit is put back into the grid circuit — *feed-back*, it is called. This is the same as though the tube were supplying its own input signal, and, once started off, the tube will continue in this way indefinitely. This is called *oscillation.*

To start oscillation in a tube fitted with a feed-back circuit, it is customary to include a *grid leak* and *grid condenser* in the circuit. When plate voltage is applied, the grid, being in the electron stream, collects a few of the electrons going to the plate. This charge is applied to the condenser, which then dissipates its charge through the leak resistance. The pulsing grid voltage thus resulting is enough of an input signal to start the tube oscillating; given this start, it keeps going by itself.

So we see how the vacuum tube is used all along the radio system. First, it converts the commercial a.c. power into d.c. for plate voltage. Second, it is used as an oscillator to generate r.f. power (and also as a power amplifier to increase that power in the larger transmitters). Third, it is used as a detector to convert the r.f. signal into intelligence. Finally, it is used to amplify the weak signals into usable quantities.

## THE AMATEUR BANDS

Let us now take a look at the shortwave (or high frequency) territory of radio, and get some idea of where amateurs fit into the picture.

The regular broadcasting band extends from 535 to 1600 kc., or from 560 to 187.5 meters. When we speak of the short waves we refer in general terms to the territory below a dividing line of 200 meters.

Years ago there was a time when none of the commercial or government radio people thought that any of this territory was useful for communication purposes and, in fact, until the advent of vacuum tubes for transmission and reception it was not feasible to operate radio apparatus at short wavelengths if any great amount of power was involved. So for many years the short-wave field slumbered on, waiting for those days beginning about 1923 when amateur experiments suddenly revealed that short wavelengths were not only useful for practical communication purposes but in many respects were far superior to the long waves previously employed in all commercial work. And, of course, when this was found to be the case, the commercial world immediately became interested in securing short-wave assignments. Government stations, commercial land and ship stations, airplanes, police radio systems — these and many others, in addition to the pioneering amateurs, wanted their share of the short-waves. The result was that each type of service was assigned certain specific bands, and thereafter all operation by any particular service had to take place only in its own bands.

It may be interesting to you to know that the number, location and size of these bands are decided upon at radio conferences (some national and some international in scope) which direct how much of the high-frequency territory shall be given to each type of service. And it is in order at this point to mention that the ARRL is recognized both in this country and abroad as the official spokesman for the amateurs of America, and that it has had its representatives in active attendance and participation in every radio conference for twenty-five years on behalf of amateurs.

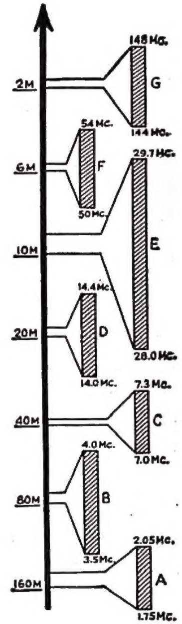



*Fig. 1* — **The major amateur bands as set up by The Federal Communications Commission. Additional higher frequencies, not shown in this chart for lack of space, are listed on the next page.**

Now, getting back to these conferences: since, when it comes to the high frequencies, there is a demand for more "channels" than there are channels available, the eventual assignments of territory represent a compromise mutually arrived at by the various interests. The amateur frequency bands are based upon allocations originally determined internationally at a conference held in 1927 at Washington, D. C., continued in effect through 1944 by subsequent international and regional conferences, and in 1945 somewhat revised by the Federal Communications Commission after extensive hearings at which ARRL again represented the amateur service. The FCC revision will be proposed on a world-wide basis at the next international conference, and some amateur frequencies may not be released until then. As a new amateur, you should not attempt to work in all bands without checking first with *QST* or ARRL Hq. at West Hartford, Conn., to see if the band you want to use has actually been released from war service for ama-

teur use. As this booklet went to press, the frequencies 3500–4000, 7150–7300, 14,100–14,300 kc. and all those assigned above 27 Mc. had been released to amateurs. Let us see where these amateur channels, as set up by FCC, are located:

### Below 200 Meters

Suppose we draw a long line to represent the short-wave territory below 200 meters — or, since practically all references are to *frequencies* rather than to wavelengths (and you should start now to think in terms of frequencies), from 1500 kilocycles up. The major frequency bands assigned to amateurs, and their relative widths, are shown in Fig. 1. All the spaces in between belong to other kinds of radio services. The proportions of the different bands are shown where the thin horizontal lines touch the heavy vertical line. Then another picture of each band is drawn off to the right-hand side, to analyze it further. The figures are in *megacycles*, meaning millions of cycles or thousands of kilocycles; thus, in the middle of the column, 28.0 Mc. means the same as 28,000 kilocycles.

You may wonder why amateurs have several narrow bands instead of one single band equal to all the narrow ones put together. That is a perfectly good question and we will explain the reason briefly. Just as the high frequencies (short waves) behave differently than the lower frequencies (medium and long waves) so some of the high frequencies exhibit different characteristics than others. The basic reason for the DX (distance) ability of all the high frequencies is the habit of most of the transmitted energy of shooting up into the air at an angle, then being bent by refraction in the ionized upper atmosphere and coming down to earth again. In traveling through the ionized region some of the energy of the wave is absorbed, and since this absorption is greatest for the lower frequencies, the higher-frequency waves can travel the longer distances, generally speaking. Thus, the comparatively low frequencies of 3500–4000 kc. work best, on the average, for moderate distances — up to one or two thousand miles, we might say. The amateur band *B* therefore, is essentially a medium-distance band. Band *C* gives us satisfactory communication for greater distances, several thousand miles on the average and up to 10,000 miles under favorable conditions. Signals in Band *D* will readily travel half-way around the world, as will those in Band *E* at certain times of the year and during certain years of the sunspot cycle. As we go upward in frequency, however, the bending in the upper atmosphere becomes less and less, and eventually a frequency is reached at which the bending is too small to bring the wave back to earth. Bands *F* and *G* are called very-high-frequency bands; the sky wave is only occasionally useful on *F* and practically never on *G*. Communication on these bands and higher-frequency amateur channels, then, is ordinarily limited to only a few times the horizon distance. This very property, though, makes it possible to do short-distance work without much interference. Interesting experimental work is under way in these bands. Additional frequencies available to amateurs, for lack of space not shown in the chart, are:

27,185–27,455 kc. (shared)
235– 240 Mc.
420– 450 Mc. (temporarily 420–430, 50-watts antenna power)
1215– 1295 Mc.
2300– 2450 Mc.
5250– 5650 Mc.
10,000–10,500 Mc.
21,000–22,000 Mc.

## LEARNING THE CODE

In all probability the first thing you will do will be to start building the receiver. But simultaneously with that you should also start learning the code. You can memorize it while you are constructing the receiver and then can use the completed receiver to listen-in and get code practice while the transmitter is being assembled and while you are "boning up" for your license examination. Thus by the time your transmitter is completed and you are ready to apply for your license you will probably find that the practice you have had with your receiver will have fully qualified you for the code-speed requirement in the amateur operator examination.

Learning the code is the first stumbling-block for some people. But it has to be learned — the government won't issue you any kind of an amateur license until you know it. Don't let it worry you; it really isn't at all difficult. The entire alphabet can be memorized in one or two evenings. A few weeks' practice listening in to code transmissions with the receiver described herein will develop speed. If you make up your mind to settle down and lick the code within a few weeks, you will be surprised to see how fast you progress.

The alphabet, numerals and punctuation marks are shown in Fig. 2. First of all, memorize these characters. Start by memorizing the alphabet, disregarding the numerals and punctuation marks for the present. There are several ways to memorize the alphabet. One way is to take the first five letters — *a, b, c, d* and *e* — and learn them, and then take the next five, and so on. On the other hand, some people like to group the alphabet into so-called memorizing groups, somewhat as shown in Fig. 3. Try whichever grouping you think will be easier for you.

Another suggestion: Learn to think of the letters in terms of *sound* rather than their appearance as they are printed. Do not think of *a* as "dot-dash" but think of it as the sound "dit-

| | | |
|---|---|---|
| A | •— | dit-dah |
| B | —••• | dah-dit-dit-dit |
| C | —•—• | dah-dit-dah-dit |
| D | —•• | dah-dit-dit |
| E | • | dit |
| F | ••—• | dit-dit-dah-dit |
| G | ——• | dah-dah-dit |
| H | •••• | dit-dit-dit-dit |
| I | •• | dit-dit |
| J | •——— | dit-dah-dah-dah |
| K | —•— | dah-dit-dah |
| L | •—•• | dit-dah-dit-dit |
| M | —— | dah-dah |
| N | —• | dah-dit |
| O | ——— | dah-dah-dah |
| P | •——• | dit-dah-dah-dit |
| Q | ——•— | dah-dah-dit-dah |
| R | •—• | dit-dah-dit |
| S | ••• | dit-dit-dit |
| T | — | dah |
| U | ••— | dit-dit-dah |
| V | •••— | dit-dit-dit-dah |
| W | •—— | dit-dah-dah |
| X | —••— | dah-dit-dit-dah |
| Y | —•—— | dah-dit-dah-dah |
| Z | ——•• | dah-dah-dit-dit |

| | | |
|---|---|---|
| 1 | •———— | dit-dah-dah-dah-dah |
| 2 | ••——— | dit-dit-dah-dah-dah |
| 3 | •••—— | dit-dit-dit-dah-dah |
| 4 | ••••— | dit-dit-dit-dit-dah |
| 5 | ••••• | dit-dit-dit-dit-dit |
| 6 | —•••• | dah-dit-dit-dit-dit |
| 7 | ——••• | dah-dah-dit-dit-dit |
| 8 | ———•• | dah-dah-dah-dit-dit |
| 9 | ————• | dah-dah-dah-dah-dit |
| 0 | ————— | dah-dah-dah-dah-dah |

| | |
|---|---|
| Period | •—•—•— |
| Comma | ——••—— |
| Question mark | ••——•• |
| Error | ••••••••• |
| Double dash ($\overline{\text{BT}}$) | —•••— |
| Wait ($\overline{\text{AS}}$) | •—••• |
| End of message ($\overline{\text{AR}}$) | •—•—• |
| Invitation to transmit | —•— |
| End of work ($\overline{\text{SK}}$) | •••—•— |

*Fig. 2* — The Continental Code.

dah." *B*, of course, would be "dah-dit-dit-dit," etc.

After you have memorized the alphabet (don't worry about speed yet) you should memorize the

| | |
|---|---|
| • E | — T |
| •• I | —— M |
| ••• S | ——— O |
| •••• H | |
| •— A | —• N |
| •—— W | —•• D |
| •——— J | —••• B |
| •—• R | ••— U |
| ••—• F | •••— V |
| •—•• L | |
| —•— K | ——• G |
| —••— X | ——•• Z |
| —•—• C | •——• P |
| —•—— Y | |
| ——•— Q | |

*Fig. 3* — The alphabet in memorizing groups.

numerals. These are easy. You will observe they follow a definite system, and you will probably learn them very quickly. Then you should learn the signals for the various punctuation marks, always remembering to think in terms of the *sound* the signals make.

When you feel that you know all these in your own mind, without hesitating over them, you are ready to develop speed.

The best way to develop speed is for two people to learn the code together. If you can find someone who will help you do this, the two of you should buy a buzzer and key, hook these up to a couple of dry cells, and send to each other. Figs. 4 and 5 show how a buzzer and key should

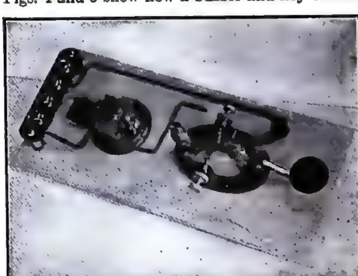


*Fig. 4* — A buzzer code practice set.

be connected. By taking turn and turn about it is remarkable how soon speed will be picked up. Another good thing about this sort of practice is that it develops ability in sending, too, because the fellow who is receiving will be quick to criticize indistinct and uneven sending.

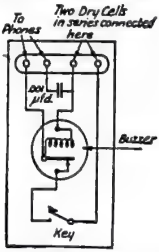



*Fig. 5* — Circuit of the buzzer code practice set shown in Fig. 4. The 'phones are connected across the coils of the buzzer with a condenser in series. The size of this condenser determines the strength of the signal in the 'phones. Should the value shown give an excessively loud signal, it may be reduced to 500 or even 250 μμfd.

If you are unable to get someone to practice with you, we would still suggest that you get a buzzer and key (you can always use the key later, in the transmitter) and "send to yourself." This helps at the start. After a little practice along these lines, you should get on the air with your receiver and listen to actual signals being sent out by other amateurs. Most of them will be faster than you can copy — but don't mind that. Every time you hear a letter that you recognize, write it down, even if it is only every fifth or tenth letter. The point is to keep at it and make a real effort to copy every letter you possibly can. Do not be alarmed if you copy several consecutive letters and they don't make sense — many amateurs use abbreviations that will be unintelligible to you, at first.

Transmissions of the special addressed messages to all radio amateurs (Official Bulletins) from the ARRL Headquarters station, W1AW, make excellent code practice. An automatic transmitter is used on these transmissions, and the messages are sent at constant rates of speed. This provides good practice for the man who has memorized code, or wants to increase his receiving speed. When one can receive the 15-word-per-minute speed "solid," he can be fairly sure of himself on the examination (at 13 w.p.m.) even though a trifle nervous. A special booklet, *Learning the Radiotelegraph Code,* may be obtained by sending 25¢ to the American Radio Relay League, West Hartford, Conn.

W1AW transmits by simultaneous telegraph tape transmissions on 3555, 7145, 14,280, 29,150, and 52,000 kc. at 8 P.M. EST (daylight saving time during May–August) and again at 11:30 P.M., each night of the week. Voice transmission, in turn, follows the completion of the official telegraph messages on each of the following frequencies: 3950, 7145, and 14,280 kc. Because of rapidly-changing conditions in amateur radio during the early postwar era, some of these schedules may change and it would be well to check with *QST* for possible recent changes.

W1AW also sends code practice on the above c.w. frequencies every week night at speeds from 15 to 35 w.p.m. in steps of 5 w.p.m. The present schedule starts at 10 P.M. E.S.T. See *QST* for latest information. This is splendid for building up your code speed.

It is probably safe to say that the majority of the amateurs on the air today learned the code by listening on their receivers. Keep at it — try to get in a few minutes at your receiver every day. Before you know it, you will be copying solid sentences.

When you can consistently copy 13 words a minute (65 letters), you are sufficiently well equipped on this score to pass the government code-speed requirement in connection with your amateur operator's license. It is a good thing, of course, to learn to copy a little faster than 13 words a minute before you take your license examination, because if you are like most amateurs you will get just a little rattled when you actually go to take your test, and it is wiser to be on the "far" side of 13 words a minute than on the "near"! Concentrate on the less frequently used words and characters, too.

## BUILDING THE RECEIVER

THE construction of the receiver should be started as soon as one begins to learn the code. Building the receiver gives one a familiarity with radio parts and construction, and the finished product will enable the operator to boost his code speed by listening to short-wave amateur and commercial stations. The experience gained in tuning different stations will stand the operator in good stead when he obtains his license and starts actual two-way communication with other amateur stations.

While almost every amateur builds his own transmitter, many of them buy factory-built receivers because the complex multistage receivers can be had from dealers for little more than the cost of the components. You may prefer to buy your receiver, new or second-hand, or to assemble a simpler one from one of the kits on the market. However, we are going to describe one that you may build yourself because it is easy and cheap to do, and thereby you will learn a great deal about how radio works — information that will always be useful to you.

The receiving sets we describe are of simple

# A Radio Amateur

design and are quite inexpensive. They are easy and straightforward to assemble and operate and, with a suitable antenna and ground, are capable of bringing in amateur and other short-wave signals from distant places. The two receivers are practically identical from an electrical and operating standpoint, but the mechanical features have been made different to illustrate methods of construction. The receivers can be used either with standard metal tubes or, for portable and other operation where batteries must be used, with the battery octal-base tubes. Thus the receiver can serve as the station unit and also as a battery-operated portable when the occasion arises, although the performance with the metal tubes is better, because of the improved characteristics of the tubes.

In describing these units, as well as the others which follow, the use of picture diagrams has been avoided. One reason for this is that such diagrams are not acceptable in license examinations, the use of standard symbols being compulsory. A second reason is that the schematic diagrams, once understood, are far less confusing than picture diagrams. A list of the more generally used symbols is given on Cover II.

The receivers shown here will enable you to tune in on practically all the useful high frequencies (short-waves) so that you can hear stations at almost any hour of the day or night. Many of them will be sending slowly, giving plenty of opportunity for code practice. To cover the wide frequency range, a number of interchangeable or "plug-in" coils are used in the receiver, but these are not difficult to make or adjust.

General views of the receivers are given in Figs. 6, 7, 8, 10, 11, 12, 13 and 15, and the circuit diagram is shown in Fig. 9. A complete list of the parts needed is given, and the symbols ($C_1$, etc.) identify the parts as shown in Fig. 9 and the various photographs. There is no difference between the two receivers other than that one is mounted on a wooden base and the other on a metal one. The metal one can be used in conjunction with a metal cabinet, or, if desired, a wooden cabinet might be built for the wood-metal version.

Before actually deciding which receiver to build, it might be a good idea to explain just how they work. When a radio wave strikes the antenna, a very small current flows in the circuit formed by the antenna, the coil $L_2$ and the ground connection. This current causes a radio-frequency voltage to be induced across $L_1$. The tuning condensers, $C_1$ and $C_2$, are adjusted so that the circuit is *resonant* with (or tuned to) the same frequency as the signal, so that other waves of different frequency which may strike the antenna will be discriminated against, or "tuned out." The radio-frequency voltage so developed is applied between the grid and cathode of the detector tube through the grid condenser, $C_4$,

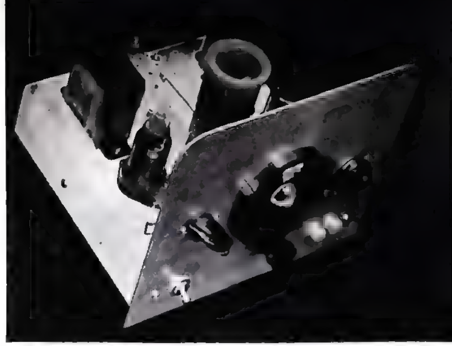


*Fig. 6* — A view of the completed wood/metal version of the receiver, with a coil in place in the socket.

across which is connected the grid leak, $R_1$; and is "detected" or made audible by the action of the grid condenser and leak and the grid circuit of the detector tube. The radio-frequency voltage at the grid of the tube also causes a radio-frequency current to flow in the screen-grid circuit through $L_3$ and $C_5$ to ground (the wire to which the "B −" connections are made, and which in turn is grounded as indicated by the "GND." post on the diagram) and thence to the cathode. The radio-frequency current flowing through $L_3$ ("feed-back") causes a further voltage to be induced in $L_1$ which reinforces the original signal. The amount of feed-back or regenerative amplification is controlled by the setting of $R_4$, which controls the screen-grid voltage and hence the amplification. When the feed-back reaches a certain critical value the detector tube will generate oscillations of its own and further amplification ceases. The most satisfactory way to operate the tube is to set $R_4$ just below the point at which the detector tube starts to oscillate, if modulated signals such as those from a radiotelephone are being received, and just beyond the oscillating point if continuous-wave telegraph signals are to be picked up. In the latter case the oscillations generated by the detector tube "beat" with the incoming signal and an audible note or whistle results; we listen to this whistle when we say we are "copying c.w. signals."

The detected signal is then passed on to the audio coupling apparatus, $L_4C_8R_2$, through a radio-frequency choke coil, *RFC*, which prevents radio-frequency currents in the plate circuit of the detector tube from getting into the audio amplifier. The radio-frequency by-pass condensers, $C_6$ and $C_7$, provide a low-impedance return path for any stray r.f. that may try to get into the audio system but have little effect on the audio signal. The audio-frequency current flowing in $L_4$ causes a voltage to appear across $R_2$, through $C_8$. This audio voltage is applied between the grid and cathode of the audio amplifier tube, which increases or "amplifies" the signal. The

resistor $R_3$ is used to develop grid bias for the tube so it will operate properly; condenser $C_9$ by-passes the audio-frequency currents around $R_3$. When filament-type tubes are used for low battery-drain portable operation, the bias for the amplifier tube is furnished by a 4½-volt battery, since the cathode resistor type of grid bias is not readily obtained with filament-type tubes.

There is one more point about the circuit to be explained before getting down to the constructional work. The detector tuned circuit consists of the coil $L_1$ and the two variable condensers $C_1$ and $C_2$, $C_2$ being connected across the whole of the coil and $C_1$ across only part. The purpose of this arrangement is to give "bandspreading"; that is, a small slice of the high-frequency spectrum is made to cover a large part of the tuning dial. As shown in Fig. 1, the amateur bands are rather widely separated groups of frequencies; if the receiver has continuous range the number of kilocycles covered on each plug-in coil will be very large and an amateur band will represent only a small portion of the range. Tuning would also be difficult; the dial would have to be set with extreme care because the space occupied by each station would be little more than a knife edge. But with bandspreading we pick out one section of the spectrum — for example, an amateur band — and make that number of kilocycles occupy the whole dial. This effect is obtained by connecting the small tuning condenser, $C_1$, across only part of the coil. The particular part of the spectrum to be spread out is selected by adjusting $C_2$, the "band-setting" condenser. The taps on the coils, as given later in the table of specifications, will spread each amateur band so that it occupies very nearly the whole of the tuning range on $C_1$ when $C_2$ is properly set. $C_2$ also can be used as the tuning condenser when general coverage, not bandspread, is wanted.

Although the uninitiated might gather from the photographs that two different receivers are being described, we wish to point out that both receivers use exactly the same circuit and constants. It was felt desirable to describe two different types of construction so that the potential amateur can select the one best suited to his talents and available tools and material. The performance of the two receivers is practically identical. Either one can use either metal tubes or the 1.4-volt battery tubes, the only changes necessary being the substitution of the tubes, coil changes and a modification of the power connections. The metal tubes will give slightly better performance because of their higher gain and lower susceptibility to mechanical vibration, but the low-voltage filament tubes are usually more desirable for portable operation or in districts where a.c. power is not available.

## CONSTRUCTION OF THE WOOD/METAL RECEIVER

The construction of the receivers is almost self-evident from an inspection of the photographs. The one pictured in Figs. 6, 7, 8 and 10 uses a wooden baseboard and a metal panel. The wooden baseboard is made by cutting a piece of ½-inch stock 7 inches square and nailing side pieces on three sides to form a base which measures 7 inches by 7 inches on the top and 2 inches high all around. Finishing nails are used to fasten the wood together.

The top view of the set shows clearly how the parts are arranged on the base and panel. The sockets for the two tubes and the power-supply plug (at the rear) project partly through the

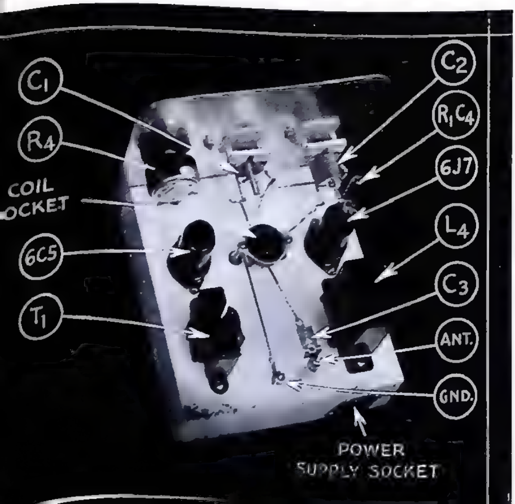
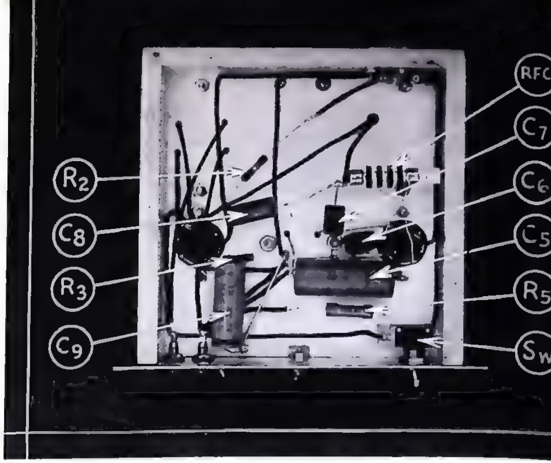



*Fig. 7* — A plan view of the wood/metal version of the beginner's receiver. The parts are labeled for easy identification.

*Fig. 8* — A view underneath the chassis shows more of the wiring and the placement of the rest of the parts. Note the ground lead from the panel, shown at the lower end of $C_9$. Part of the base must be cut away to accommodate a dial-mounting screw.




base, the mounting rings being flush with the top. A wood brace with an expansion bit will cut the socket holes cleanly. Each hole should be just large enough to pass the socket — about 1⅛ inches in diameter — and the centers should be 2⅝ inches back from the panel and 1¼ inches in from the edges of the baseboard. The sockets are held down by small wood screws or by bolts running through the base and fastened with nuts on the underside.

The coil socket is midway between the two tube sockets and is also 2⅝ inches behind the panel. This socket is supported by two 1½-inch 6-32 bolts. The socket ring is held firmly on the head end of the bolts by tightening nuts on the under side of the ring, and the bolts are then run through holes in the base and held firmly by nuts and washers on both sides. If small brass pillars are available to slip over the bolts, they can be added for some slight additional strength.

The coil socket is mounted with the two large holes facing towards the right-hand side of the set (looking at the receiver from the front) and the tube sockets are mounted with the notches on the centering holes towards the panel. The orientation of the power-supply plug socket is immaterial; it is mounted on the side at the right-hand rear of the base.

The antenna terminal is made from a small porcelain stand-off pillar, secured to the base by a bolt from the underside, and a bolt is screwed in at the top of the pillar (after the head of the bolt has been sawed off) and locked in place by a nut. The antenna condenser, $C_3$, is then slipped over the bolt and held in place by another nut. Two washers are then slipped on the bolt and a final nut completes the assembly, which serves as a support for the condenser and also as the antenna binding post. The ground post is made from a bolt through the baseboard which has a convenient soldering lug held in place by a washer and the bottom nut.

The choke, $L_4$, and the transformer, $T_1$, are held in place by wood screws or bolts, and holes are drilled in the base for the wires from these components. Holes should also be drilled in the base under pins B, E and F so that wires may be run under the base from these terminals.

The arrangement of parts on the panel will become clear after inspection of the front and top views. The condensers $C_1$ and $C_2$ are supported on the panel by bolts fastening to the mounts provided on the condensers. Large holes are drilled to clear the shafts. In this manner, the condensers are not fastened directly to the panel as is done in some cases, and it eliminates the possibility of poor connections. The dial is fastened by the three bolts provided for the purpose, and it should be centered carefully so that there is no tendency towards binding, which might keep the dial from working smoothly. Some dials of this type are made with only two mounting bolts, but this type should be avoided because it is practically impossible to make it lie flat on the face of the panel. If the dial slips at all, loosen up on the mounting bolts a bit. The National-type dial used on the all-metal receiver is smoother working but more expensive.

The panel is made from a piece of 1⁄16-inch aluminum cut 7 inches by 8 inches. After all of the holes have been drilled, it can be immersed for 20 or 30 minutes in a water bath in which some lye has been dissolved. A half-can of lye to a gallon of water is about the right proportion, but the ratio is not at all critical. This will take the bright shine off the aluminum and render it less sensitive to finger marks. The tuning condenser, $C_1$, is mounted exactly in the center of the panel. The band-set condenser, $C_2$, and the regeneration control, $R_4$, are mounted 2½ inches away on

either side, at the same height. The switch, *Sw*, and the phone-tip jacks are mounted at a height of 1 inch from the bottom of the chassis and directly under $C_2$ and $R_4$, respectively. Although other materials than aluminum could be used, the panel should be of metal, to act as a shield. This simple shielding prevents "body capacity" effects which cause a shift in the receiver tuning when the hand is brought near the radio-frequency circuit. The panel is held to the baseboard by four wood screws.

The remaining receiver parts are mounted underneath the baseboard. They can be identified readily in Fig. 8. Although the exact placement of parts is not critical, the general arrangement shown should be followed, since it results in short radio-frequency leads and also lends itself to convenient wiring.

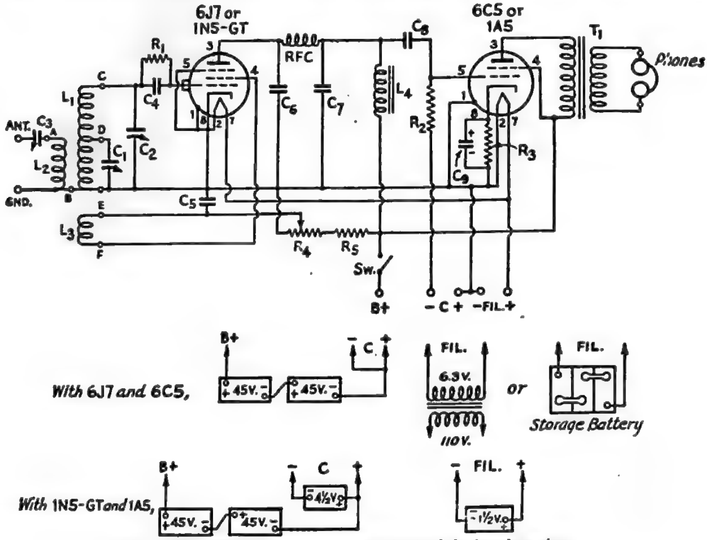



*Fig. 9* — Wiring diagram and list of parts for the simple beginner's receiver.

NOTE: The connection indicated above to the No. 4 pin on the audio amplifier socket need not be made if dry-battery tubes are not to be used, since the 6C5 has no second grid.

$C_1$ — 35-μμfd. midget variable (Millen 20035 or Hammarlund HF-35).
$C_2$ — 100-μμfd. midget variable (Millen 20100 or Hammarlund HF-100).
$C_3$ — 3-30-μμfd. mica trimmer condenser (Millen 26030, Hammarlund MEX or National M30).
$C_4$ — 100-μμfd. midget mica (Mallory).
$C_5$ — 0.5-μfd. 400-volt paper (Mallory).
$C_6$, $C_7$ — 0.0005-μfd. midget mica (Mallory).
$C_8$ — 0.01-μfd. 600-volt paper (Mallory).
$C_9$ — 10-μfd. 25-volt electrolytic (Mallory).
$R_1$ — 2-megohm 1-watt carbon (Centralab).
$R_2$ — 0.5-megohm ½-watt carbon (Centralab).
$R_3$ — 1000-ohm ½-watt carbon (Centralab).
$R_4$ — 25,000-ohm wire-wound potentiometer (Clarostat).
$R_5$ — 15,000-ohm 1-watt carbon (Centralab).
$L_1$, $L_2$, $L_3$ — See Fig. 14.
$L_4$ — 300-henry audio choke (Thordarson T67C46) (larger values of inductance may be used).
$T_1$ — Audio transformer (Thordarson T13A34).
Sw — Single-pole single-throw toggle switch.
RFC — 2.5-mh. radio-frequency choke (National R-100U or Millen 34100).

Baseboard or metal chassis (Par-Metal 7 × 7 × 2).
Panel, aluminum or one furnished with cabinet (Par-Metal CA-200).
Tuning dial (Eby, or National Type B).
Two pointer knobs.
Five 6-prong coil forms (Hammarlund SWF-6).
Two octal sockets (Amphenol MIP).
One 6-prong socket (Amphenol MIP).
One 5-prong socket (Amphenol MIP).
One 5-prong cable plug (Amphenol) or old tube base.
One small stand-off insulator (National GS-10).
Four- or five-wire cable.
Two pin jacks (Amphenol or American Hardware).
One small grid cap.
Wire, screws, etc.
One Type 6J7 or 1N5-GT.
One Type 6C5 or 1A5.

The following accessories will also be needed:

One pair headphones.
One 6.3-volt filament transformer or 6-volt storage battery (1½-volt dry cell if battery tubes are used).
Two 45-volt medium-size "B" batteries.
One 4½-volt "C" battery (if battery tubes are used).

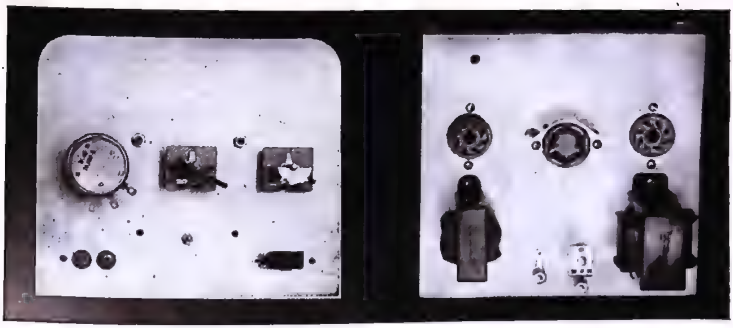


*Fig. 10* — The components mounted on the wood base and metal panel before the wiring is done and before the panel is attached. The hole in the upper left-hand corner of the base takes the wires from the regeneration control. Blank holes on the panel are for the screws that fasten the panel to the base. The three nuts hold the dial to the panel.

The wiring is fairly straightforward and need not be a cause for concern if the diagram, Fig. 9, is followed carefully. Connections in the tuning circuit (between the variable condensers and the coil socket) are made with bus wire as shown in Fig. 7. A wire from the rotor of $C_2$ goes to the rotor of $C_1$ and thence to B on the coil socket. Another wire from B goes through the base and over to the No. 2 pin of the detector socket. A wire from a soldering lug slipped under a mounting screw on the panel, runs over to the point where the ground wire comes through the base and thus grounds the panel. Finally, a wire from B is run to the ground binding post at the rear of the set.

The grid condenser, $C_4$, and the grid leak, $R_1$, are mounted on the stator terminal of $C_2$, being soldered directly to the lug. Thus only a short connection is needed to run to the grid cap of the tube and there is little tendency to pick up hum from nearby power wires. The grid lead is not soldered to the grid of the tube but is fastened with a small "grid cap" which permits easy removal of the tube.

Pieces of bus wire are used to connect the stators of the tuning condensers to the proper coil socket terminals, and another piece of the wire is used from F on the coil socket to the screen-grid pin (No. 4) of the detector socket. The rest of the connections are made with smaller "push-back" wire, which is very convenient for wiring since the insulation can be slid back to expose enough of the wire for soldering. Neither the bare bus wire nor the push-back requires scraping or flux.

Of the three wires from the variable resistor, $R_4$, the one from the right-hand side (looking at it from the back) goes to the ground bus, the center one runs over to one side of $C_5$, and the third terminal connects to switch *Sw* through $R_5$. Connected in this manner, turning the knob clockwise will increase the screen voltage and consequently the feed-back.

In connecting $C_9$, be sure the "plus" terminal goes to the No. 8 pin on the amplifier tube socket. The "minus" terminal should connect to the common ground wire. If this connection is not made properly, the condenser will not function correctly and may be damaged.

The rest of the wires are placed in convenient positions, and a study of Fig. 8 will furnish a clear picture of how to run the leads. The sequence of the connections on the power-plug socket is of no importance, and it can be made anything that is convenient. The switch, *Sw*, in the positive "B" lead, is necessary so that the battery plate supply will not be wasted during transmission periods. The heater or filament power, which is left on during any operating period, is most conveniently disconnected at the source, whether it be battery or transformer.

## CONSTRUCTION OF THE ALL-METAL VERSION

The construction of the all-metal receiver differs from the wood-metal version in only a few points. The components on top of the 7 × 7 × 2-inch chassis are mounted the same way as on the wood version with the exception of the ground binding post. A hole is drilled for the post and the paint is scraped away on the underside so that the bolt used for the binding post makes good contact with the metal chassis. Holes in the chassis for leads from E and F on the coil socket are made large enough to accommodate small rubber grommets which insulate the wires running through the holes from the metal. A sol-

dering lug is fastened under the supporting bolt adjacent to the hole under B, and the wire from B solders to this lug to form a ground connection. The paint is, of course, scraped away at the bolt so that the lug makes contact with the chassis. The holes for the sockets can be made with a metal-worker's circle cutter or with any of the several punches sold for the purpose. The diameter of the holes should be 1⅛ or 1³⁄₁₆ inches. The socket mounting rings are held to the chassis with small 6-32 bolts and nuts.

The panel measures 8 inches by 8¼ inches and is the one furnished with the cabinet. If a cabinet is not used, the panel can be made of aluminum, as described for the receiver with the wood base. However, if the National dial (pictured in the metal-receiver photographs) is used, it will be necessary to place the band-set condenser, $C_2$, and the regeneration control, $R_4$, 2¾ inches away from the main tuning condenser, $C_1$, so that the knobs will clear the edge of the dial. $C_1$ is placed in the center of the panel, as before, and the switch, *Sw*, and the phone tip jacks are centered under $C_2$ and $R_4$ respectively, at a height of 1 inch from the bottom of the panel.

The panel is held to the chassis by four bolts, but washers or nuts are used between the panel and chassis to space them apart slightly. This is necessary if a cabinet of the type shown is used because of the small lip at the bottom of the cabinet front. If no metal cabinet is used, the panel need not be separated from the chassis. Spacing the panel from the chassis requires that the switch, *Sw*, be mounted on the chassis, with enough of the hub projecting to show through the hole in the panel, while the insulated phone tip jacks are mounted on the panel and project through clearance holes in the chassis, since the jacks must not ground to the chassis.

It will be noted that the band-set condenser, $C_2$, is mounted in a slightly different plane than in the wood-metal version. This was done to illustrate how, by only a slight rearrangement of parts, leads can often be shortened. In this case, the lead from the rotor becomes shorter. This is of no practical importance on the frequencies for which this receiver is designed, but it is a point to bear in mind when the amateur starts to design his own equipment later in his career. It is important to keep leads short that are carrying radio-frequency currents — the length of leads carrying direct or low-frequency alternating current is not important.

As with the wood-metal receiver, the tuning condensers, $C_1$ and $C_2$, are not grounded to the panel at their mounting, and the holes that take

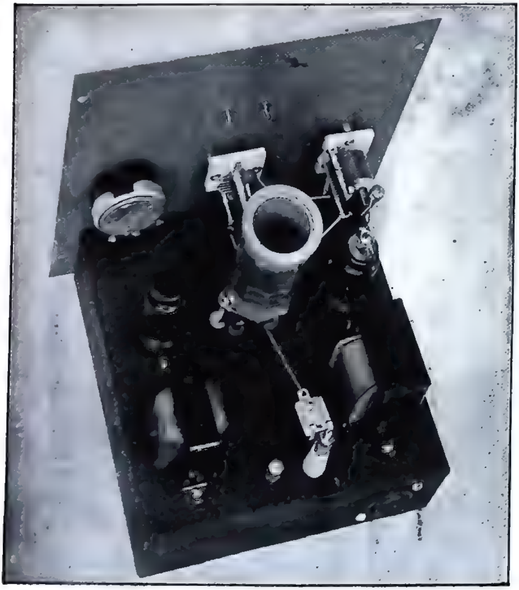


*Fig. 11* — A plan view shows the arrangement of parts to be identical with that of the wood-metal version with the exception of the plane of the band-set condenser, $C_2$.

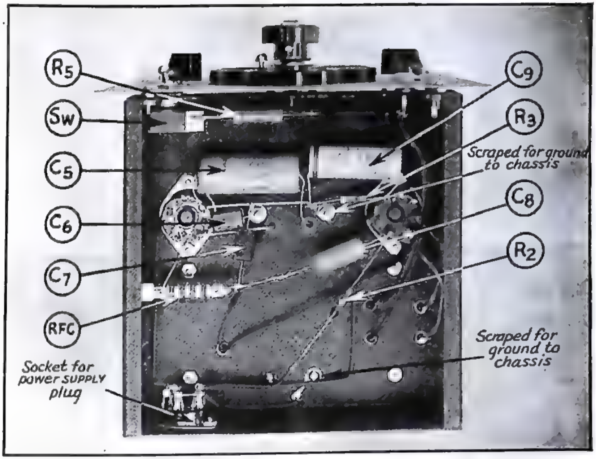



*Fig. 12* — The underside of the chassis, showing how the panel is spaced away from the chassis (necessary only when a cabinet is used).

the shafts must be large enough so that the shafts do not touch the panel at any point.

The wiring of the metal version is similar to the wood/metal receiver, with minor exceptions of the ground leads as described above, and need not be repeated here.

## WINDING THE COILS

COIL data are given in the table in Fig. 14, and should be followed closely as a start. When starting to wind a coil, first solder one end of the wire in the proper pin, after threading the wire through a small hole in the coil form. Then secure the distant end of the wire (after unwinding from the spool as much wire as is judged necessary for the coil) to a doorknob or other convenient point, and wind the coil by stretching the wire taut and walking toward the far end of the wire as the coil form is revolved in the hand. This will wind the wire tightly on the form and result in a much better-looking coil than if the form is held and the wire wrapped around. When the proper number of turns has been wound on the form, the wire is cut a foot from the form and this end threaded through the proper hole and pin in the form. The insulation is then scraped from the end of the wire brought through the pin, and the wire is soldered to the pin. The important thing is to wind on the wire evenly and

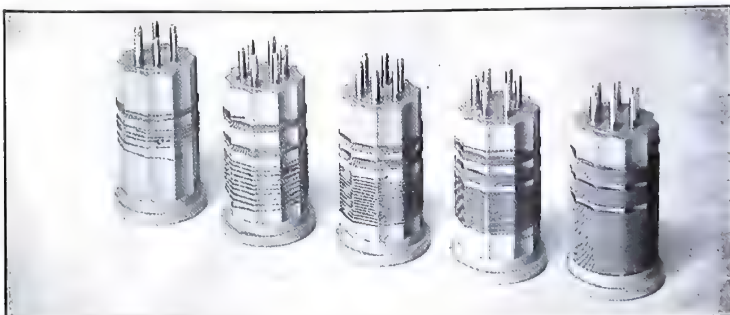


*Fig. 13* — Five plug-in coils are used to cover the frequency range from 1.55 to 33 Mc.

as tightly as possible. In the case of spaced turns, the wire is wound on first by spacing the turns by eye and, after the ends have been soldered, the turns can be moved slightly to give more even spacing, or string can be wound between the turns and then unwound.

Taps are made on $L_1$ by drilling a small hole in the form at the proper point (after the coil has been wound and properly spaced), scraping the insulation on the wire for a very small distance either side of the hole, and soldering the end of a short length of wire to the scraped portion. It isn't difficult to make a neat job if a little care is taken.

Since it is practically impossible to exactly duplicate coils, it is to be expected that some slight modifications may be necessary. However, probably the only changes necessary will be in $L_3$, the coil that determines the oscillation point of the detector. The proper value of this coil will vary with the particular antenna used, and the proper adjustment is now to be described.

## OPERATION OF THE RECEIVER

After the set is completed and the wiring checked to make sure that it is exactly as shown, insert the No. 3 coil (selected because signals can usually be heard in this range at any time of the day or night) in the coil socket and connect the headphones, antenna and ground, and the heater supply. The heater supply, as well as the plate power, is conveniently connected by means of a 5-wire cable and a 5-prong plug which fits into the socket at the rear of the set. A cable from three to five feet long will be

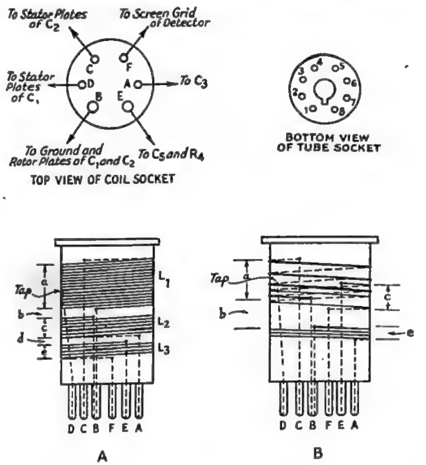



*Fig. 14* — Tube and socket connections for the receiver. All of the coils except No. 5 for metal tubes and No. 4 for battery tubes are wound as at A; B shows how coil No. 5 for metal tubes and No. 4 for battery tubes are wound. All coils for any one range must be wound in the same direction. In the table below, the values given in parentheses apply only to the battery-tube coils, otherwise the values are the same for both types of tubes.

| No. | Range, Mc. | Amateur Band, Mc. | Turns $L_1$ | Turns $L_2$ | Turns $L_3$ | Dimensions, Inches a | b | c | d | e | Bandspread Tap |
|---|---|---|---|---|---|---|---|---|---|---|---|
| 1 | 1.55–3.0 | 1.75 | 48¾ | 13½ | 13 (28) | 1⅛ | ⅛ | ⅜ | ⅛ | ⅜ (¾) | — |
| 2 | 2.8 – 6.5 | 3.5 | 22¾ | 10½ | 8½ (20½) | ⅜ | ⅛ | ¼ | ⅛ | ¼ (½) | — |
| 3 | 5.0 –10.5 | 7.0 | 15¾ | 7½ | 5½ (12½) | ⅜ | ¼ | ¼ | ⅛ | ⅛ (⅜) | 7 |
| 4 | 7.5 –16.5 | 14.0 | 9¾ (8¾) | 4½ | 5½ (5½) | ⅜ | ¼ | ⅜ | ¼ (—) | ⅛ (¼) | 2½ |
| 5 | 16.0 –33.0 | 28.0 | 3 | 3¼ | 2¼ | ½ (not recommended) | ¼ | ¼ | — | ⅛ | 1 |

All coils are wound with No. 24 d.s.c. wire on 1½-inch diameter forms. The taps are counted off from the lower end of $L_1$ (connection B); coils No. 1 and 2 are not tapped and terminal D goes directly to C inside the coil form. All $L_1$ coils are spacewound except on coil No. 1; all $L_2$ coils and $L_3$ are closewound except on coil No. 5, where $L_3$ is spacewound within $L_1$.

required, depending on where the power supply is located at the operating position. After the heater supply has been connected for a few minutes, the metal tubes should feel warm to the touch; in the case of the dry-battery tubes, they heat up instantly but there is no detectable sign that they are on. If the tubes do not warm up, the wiring should be checked. The "B" battery (and "C," if used) may now be connected and the switch, *Sw*, closed. The switch is closed when the toggle is pointing towards the side of the switch from which the terminals are brought out.

Now turn the regeneration control knob in a clockwise direction until the set goes into oscillation. This phenomenon is easily recognizable by a distinct click, thud or hissing sound. The point where oscillation just begins is the most sensitive operating point at that particular dial setting.

The tuning dial may now be slowly turned, the regeneration control knob being varied simultaneously (if necessary) to keep the set just oscillating. A number of stations will probably be heard. A little practice will make tuning easy.

If the set refuses to oscillate, the sensitivity will be poor and no code signals will be heard on the frequencies at which such signals should be expected. It should oscillate easily, however, if the coils are made exactly as shown and the tubes and batteries are good. It sometimes happens that the antenna takes so much energy from the set that it cannot oscillate, this usually resulting in "holes" in the range where no signals can be picked up (and where the hissing sound cannot be obtained). This can be cured by reducing the capacity of $C_3$ (unscrewing the adjusting screw) until the detector again oscillates. If it still refuses to oscillate, the antenna coil, $L_3$, must be moved nearer to $L_2$ or, in extreme cases, a turn or two must be added to $L_3$. This is best done by rewinding with more turns rather than by trying to add a turn or two to the already-wound coil. For any given band of frequencies, adjust $C_3$ (and possibly $L_3$) so that the detector oscillates over the whole range, using as much capacity at $C_3$ as is possible. This will give the best compromise between dead spots and signal strength. It will be found that it requires less advancing of the regeneration control, $R_4$, at the high-frequency end of a coil range ($C_2$ at or near minimum capacity) than at the low-frequency range. Since it is desirable to have the detector go into oscillation with the regeneration control advanced well towards its maximum, the best adjustment of the antenna condenser, $C_3$, and the feed-back coil, $L_3$, is that which requires almost a maximum setting of the regeneration control at the low-frequency end (maximum capacity of $C_2$) of any coil range. Once the set has been used for a while, the above will be much clearer and sound not at all complicated. Any experimenting with the coils will be amply repaid in optimum results. Coils $L_1$ and $L_2$ will require no modification if the specifications have been followed closely.

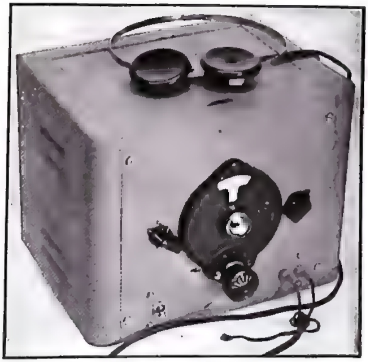


*Fig. 15* — The completed all-metal version of the receiver mounted in its cabinet and ready for use.

Coil No. 1 just misses the high-frequency end of the broadcast band, but it is possible to hear police stations as well as other services.

Locating the amateur bands is done by searching carefully with $C_2$. The 3.5–4.0-Mc. amateur band will be found on coil No. 2 at about 65 per cent setting of $C_2$; it will be easiest to locate this band by setting $C_1$ at minimum capacity (plates unmeshed) and adjusting $C_2$ until amateur 'phone stations are heard. This is best done at night, when the activity is heaviest on this band. On coil No. 3, the 7-Mc. amateur band will be found with $C_2$ meshed about 45 per cent; the 14- and 28-Mc. bands are found with $C_2$ meshed about 20 per cent and 15 per cent respectively. Of course signals can be picked up on any of the coils at random settings of $C_2$; in time you will become familiar with the tuning range of the receiver, and the process of finding a particular band — which may sound somewhat complicated from this explanation — actually will be easy.

Sometimes local broadcasting stations cause interference, especially when the lower-frequency coils are being used. A simple but effective cure for such interference is the wave trap. This is simply a coil and condenser tuned to the frequency of the broadcast station causing the trouble, inserted in the antenna lead. It acts as a rejector circuit and prevents the unwanted signal from getting through, although having no effect on signals of other frequencies. The values shown in Fig. 16 will be effective over the entire broadcast band.

A suitable antenna for the receiver would be 50 to 75 feet long, and as high and clear of surrounding objects as possible. The same precautions as to insulators that you would apply to

your broadcast receiving antenna should also be applied to this short-wave antenna. The transmitting antenna may be used for receiving, by means of a suitable switch, but it is normally

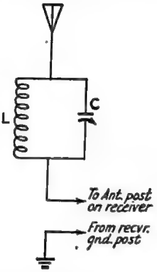



*Fig. 16* — How a wave-trap is added to the set to eliminate broadcast interference: The trap is inserted in the antenna lead-in as shown. The coil, *L*, may be 40 turns of No. 22 d.c.c. wire on a three-inch form. The variable condenser, *C*, should be 0.00035 μfd. or larger. Any coil-condenser combination which will tune to the frequency of the interfering station will be satisfactory.

more convenient to use a separate receiving antenna. Unless the building is a metal one or the room too near the ground level, a small wire run around the room and lying out of sight in the picture molding will often serve as a fair receiving antenna. The ground lead should preferably be short — do the best you can with your particular conditions. A ground to a heating radiator or any of the water piping is good. Do not use gas pipes for grounds, since the joints in these lines often are insulated, particularly at the meter.

A good pair of headphones is an excellent investment, as these will always be useful regardless of the advancement to more complicated gear as the station becomes more elaborate, and the best type that can be afforded should be bought. Lightweight headphones are quite popular, but many operators prefer the heavier ones because they clamp tighter on the ears and keep out outside noises. The price of the headphones is a good indication of the quality.

## USING THE RECEIVER

UNLESS you are a very unusual type of person it is probable that you will have your receiver hooked up to the antenna and "on the air" within a very few minutes after you have soldered the last connection and tested the set for satisfactory operation. And it is probable, too, that all other activity will be suspended for a number of days thereafter, while you learn to tune the set to best advantage, find out where the amateur bands are, and generally have a good time exploring the new world that opens up to those who venture forth into high-frequency reception.

At first it is probable that you will listen-in on all sorts of transmissions in addition to amateur signals. By careful tuning you should be able to pick up police calls when using Coil No. 1. Aeronautical signals can be heard when using Coil No. 2 and careful tuning with various of the other coils will frequently produce satisfactory reception of foreign broadcast stations. It is not unlikely that you will occasionally find yourself listening to one side of a ship-to-shore telephone conversation, and if you happen to pick up one side of a telephone speech that is so garbled that you can't quite make out what the people are saying, you are listening to one of the transoceanic radiotelephone links with a "scrambler" to assure privacy. As you become used to the receiver and your proficiency in its operation increases, you will find yourself picking up more and more material which you seemed unable to hear at first, and you will also begin to acquire a good idea of what frequencies each coil covers, and where to find a certain frequency on your tuning dial when you want to look for some particular station.

Listening-in on the high frequencies is a revelation to people who up to that time have thought that most radio transmission and reception is confined to broadcasting. A horde of radio signals from dozens of different types of services tell their story hourly to whomever will listen. Some stations send slowly and leisurely, and even the beginner can read them. Others race along furiously so that whole sentences become meaningless buzzes. There are both telegraph and telephone signals: press messages, weather reports, time signals, transocean commercial radiotelephone and telegraph messages, international broadcasting of voice and music, transmissions from government and experimental stations, airplane dispatching, police broadcasts, signals from private yachts and expeditions exploring the uttermost parts of the earth — signals jam the high-frequency spectrum from one end to the other. And sandwiched in among all these services are the amateurs, hundreds of whose stations may be heard every night.

You will soon become familiar not only with the location of the various amateur bands but with the fact that there is quite a bit of difference in the type of work carried on in each band.

The 3500-kc. band is where most of the amateur message handling and organized amateur radio work (the ARRL trunklines, the Army-Amateur Radio System net, special emergency nets, etc.) takes place and at night, particularly in the winter, stations will be heard over distances of several thousand miles. At the high end of this band, there is a 'phone sub-band, and this is always jammed with signals from more advanced

amateur telephone stations.

It is in the 7000-kc. band that much of the international transmission and reception takes place, for reasons we have previously outlined in commenting on the properties of various high frequencies. But it will probably take you some time to learn to pick out foreign stations, because of the intense interference resulting from stations all over the world operating in this popular but narrow slice of territory. However, we might caution you against assuming that foreign signals will be the weakest ones — it is one of the characteristics of high-frequency work that some of the longest-distance signals are frequently as loud or louder than signals from stations closer at hand.

Listening-in on the 14,000-kc. band in the daytime, or early evening, will bring you signals from all over the country and from foreign points as well. This is an excellent place to listen for foreign amateur telephone stations, by the way.

A word of caution: United States radio laws prescribe heavy penalties for divulging the contents of any radiogram or message to other than the addressee. You may copy anything you hear, but must preserve its secrecy — unless it is something broadcast for the general public.

## INTERPRETING WHAT YOU HEAR

Listening to police broadcasts, etc., is all very well for a short time, but you did not build your receiver just for that and within a few days it is probable that you will want to start copying amateur telegraph code transmissions, acquiring speed in receiving and gradually becoming able to understand what is going on around you.

The first symbols you will be able to identify will, in all likelihood, be the call signals of the stations calling or being called, since a call is quite easily recognized after you have listened a while and, too, because the calls of stations are usually repeated a number of times, giving you an opportunity to make out the signal the third or fourth time if you can't get it at first.

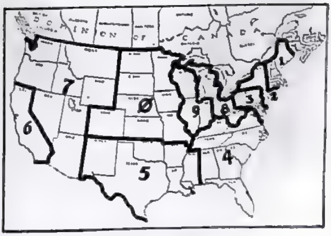
If, at the start, you confine your more serious listening to the 3500-kc. band, as we suggest you do, practically all of the stations you hear will be in the United States. All amateur calls within the boundaries of the United States consist of a prefix letter, W, followed by a figure from 1 to Ø, and then a combination of two or three letters of the alphabet. Representative U. S. amateur calls, for instance, are W1AW, W3BZ, W8CMP, WØEFC, etc. The number indicates the amateur call area (see map) and will give you a general idea of the part of the country in which the station is located.

When one station calls another it sends the call of the station being called several times, then the letters "de" (meaning "from" in French, and agreed upon internationally as the sign to separate the call of the calling station from the call of the station being called) and then its own call repeated a number of times. If you hear this on the air — W1KH W1KH W1KH DE W1AW W1AW W1AW — it means that W1AW is calling W1KH. Many times what you hear will be like this: CQ CQ CQ DE W2AEN W2AEN W2AEN. "CQ" is a general call to any station which may want to talk with the station doing the calling, and in the case we have cited means that W2AEN is indicating that he is ready to talk with anybody and will answer any station he may hear.

If you happen to break in on an amateur conversation it is probable that you will be confused at first by what you hear them sending — it will not seem to make sense. This does not necessarily mean that you are not "copying" correctly. As you may have heard, most amateurs use what are known as "ham abbreviations" to save time in talking with each other. While there is no official list of such abbreviations, a certain number have become pretty well standardized through constant use, not only in this country but throughout the world, and for your information we list some of the most popular ones, and their meanings:

| | | | |
|---|---|---|---|
| ABT | About | HW | How |
| AGN | Again | NIL | Nothing |
| AMP | Ampere | NR | Number, near |
| ANI | Any | NW | Now |
| BCNU | I'll be seeing you | OB | Old Boy |
| BK | Break | OM | Old Man (All male amateurs are "OMs" regardless of age!) |
| BTR | Better | OP | Operator |
| CRD | Card | OW | (Old Woman) A married woman operator, sometimes called "XYL" |
| CUD | Could | PSE | Please |
| CUL | See you later | RCVR | Receiver |
| DX | Distance | SED, SEZ | Said, says |
| ES | "&" | SKED | Schedule |
| FB | Fine business, excellent | TKS, TNX | Thanks |
| FM | From | TT | That |
| FR | For | TU | Thank you |
| GA | Go ahead, good afternoon | U, UR | You, your, you're |
| GB | Goodbye | VY | Very |
| GDA | Good day | WX | Weather |
| GE | Good evening | XMTR | Transmitter |
| GG | Going | YL | (Young lady) An unmarried woman or girl operator |
| GM | Good morning | 73 | Best regards |
| GN | Good night | | |
| GUD | Good | | |
| HAM | Amateur | | |
| HI | Laughter | | |
| HR | Hear, here | | |
| HRD | Heard | | |
| HV | Have | | |

There are other abbreviations used by amateurs, too, and these are the internationally-recognized "Q" signals. A list of those most likely to be heard in use by amateurs is printed in the back of this booklet. The "Q" signals constitute a handy way for amateurs (or any class of radio station, for that matter) to exchange essential information about interference, requests for changing wavelength, etc., without




U. S. Amateur Call Areas

having to spell out long sentences to get over their meaning. It should also be mentioned that it furnishes a way for two amateurs to exchange information even though neither can speak the language of the other. A Spanish-speaking Puerto Rican may send "QTH?" to an American amateur, and the American amateur will know that he is asking for his address and will thereupon say "QTH 123 Seaside Street Podunk New York" or whatever it may be.

In a very short time you will be surprised at your ability to understand the interesting conversations, message-handling, etc., which take place among amateurs, and it is then that you will begin to realize just how interesting amateur work can be.

One of the first adjuncts to your "shack" should be a callbook, so that you can locate the stations whose calls you hear over the air. The ARRL does not publish an amateur callbook but an excellent one is available known as *The Radio Amateur Callbook Magazine.* It gives the calls of all United States and foreign amateur stations, together with other information on high-frequency stations, and should be on every operating table. It may be secured for $1.50 postpaid either from the publishers (The Radio Amateur Callbook Magazine, 608 South Dearborn St., Chicago, Ill.) or from the ARRL, West Hartford, Conn., where it is kept in stock in our Book Department.

Still another way to get code practice is to tune in on one of the many amateur "Official Broadcasting Stations" which send out weekly bulletins, on amateur happenings, furnished them from the headquarters of the League. Lists of OBS stations are also published in *QST* at regular intervals. One of the most widely heard stations is the League's headquarters station, W1AW, which sends out the amateur broadcasts on the schedule given on page 10.

As you can see from this schedule, W1AW sends these bulletins simultaneously on four different frequency bands, so if you are unable to hear the station on the 3500-kc. band you may be able to pick it up on some other.

We suggest that you make a practice of tuning in on this amateur bulletin service reasonably soon in your amateur career, not only for the code practice it gives, but for the interesting information the bulletins contain on amateur happenings, coming conventions or hamfests, expedition notes, coming contests, contest results, etc.

Now that we are well "organized" for listening on the amateur bands, let us take up construction of the transmitting apparatus.

## BUILDING THE TRANSMITTER

WE HAVE previously told you how to keep your receiver on the edge of oscillation when receiving amateur signals. When the receiver is oscillating like that, it sends out a weak signal

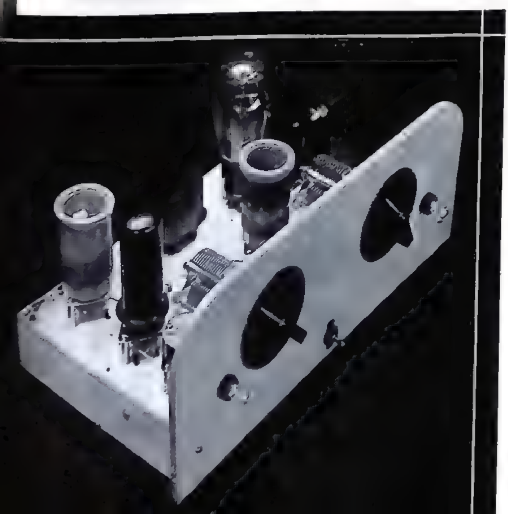


*Fig. 17* — Front view of the wood-base version of the transmitter with coils and tubes in place.

on the air; actually it is a miniature sending set. In the early days of broadcasting, when most receivers were of this type, it was quite a common thing to hear your neighbor's receiving set "whistling"; it was the same thing, precisely.

Now, when we really want a transmitter we increase the size of the tube and put more voltage on it, and then adjust it so it will oscillate all the time. The result is that it sends out a strong whistle, and this whistle is the signal that goes for hundreds and even thousands of miles. By starting and stopping that whistle with a telegraph key we can spell out the letters of the alphabet in "code," and we then say we are *sending*.

Although a transmitter can be built using the same type of circuit as that used in the receiver, the up-to-date amateur transmitter is of the type known as "crystal-controlled." There are two excellent reasons why the beginner also should use this type of transmitter. In the crystal-controlled transmitter the operating frequency is determined almost solely by the dimensions of a carefully-ground slab of quartz, so that once a quartz crystal having the proper dimensions has been purchased the amateur can be quite certain that his signals are going to be within the limits of an amateur band. With "self-controlled" oscillator circuits — so called because the frequency of oscillation is dependent upon the coil and condenser used — it is only too easy through error to set the tuning condenser to a frequency outside the amateur band, with the result that the signals will be "off-frequency." Working off-frequency is a serious offense against the amateur regulations, and is likely to get the operator into trouble with the authorities. The second reason is that because the crystal tends to oscillate at one frequency only, the signal emitted from the transmitter is highly stable; that is, the frequency remains constant despite variations in line voltage, swinging antennas, tube heating and other factors of similar nature. These variables, which are to a large extent beyond the control of the operator, all operate to change the frequency of a self-controlled transmitter, causing frequency instability. An unstable transmitter will have a wobbly and sometimes mushy or ragged note, while the highly-stable crystal-controlled type can be recognized readily because of its steadiness and clean-cut character.

The photographs show two types of construction for a transmitter, identical in all respects save that one is "breadboard" construction and the other is built on a metal chassis. A Type 6L6 receiving tube is used as a crystal oscillator, and will give a radio-frequency power output of about 10 watts. With crystals for the 3500- or 7000-kc. bands the circuit permits the crystal to operate either on its *fundamental* frequency — the frequency for which it is ground — or at its *second harmonic* — twice the normal frequency. This type of circuit, known as the *Tri-tet*, is advantageous because it makes possible the operation of the transmitter in two amateur bands with a single crystal. For instance, if the crystal itself is ground for the 3500-kc. band, output can be secured on either the 3500-kc. or 7000-kc. bands. Similarly, a 7000-kc. crystal can be used for 7000 kc. and 14,000 kc.

In Fig. 18 the circuit formed by the coil, $L_1$, and variable condenser, $C_4$ is proportioned so that it can be tuned either to the fundamental frequency of the crystal or to the second harmonic. This change may be made by changing coils, using one with a larger number of turns for the fundamental and one with less turns for the harmonic. This circuit is commonly known as the *tank circuit* because it is from it that we draw the r.f. power which goes into the antenna and is radiated. The plate power is fed to the tube through the tank coil, $L_1$, and is introduced at the end of the coil which is at low r.f. potential; that is, the end connected through by-pass condenser $C_5$ to the negative terminal of the high-voltage supply. Feeding the d.c. voltage through the tank coil in this manner is known as *series feed*.

The wire to which the negative terminal of the power supply is connected, and at which the various by-pass condensers, $C_3$, $C_5$ and $C_6$ are connected, usually is referred to as the *common ground* connection; that is a direct connection to earth, if made, will not disturb the operation of the circuit, since there is no difference of potential or voltage between this wire and the earth. It should be understood that a reference to a connection to ground means a connection to this common wire and not literally to a connection to the earth itself.

As shown in Fig. 18, the crystal is connected between the grid and cathode of the tube. Between grid and the common ground wire an r.f. choke coil and resistor are connected in series; $R_1$ is known as the *grid leak*. When the tube is oscillating, the r.f. voltage on the grid causes a direct current to flow in the grid-cathode circuit because of the rectifying properties of the tube, and this current flowing through $R_1$ causes a voltage to be developed which biases the grid. This *grid-leak bias* is important in making the tube operate efficiently.

Between the cathode of the 6L6 and the by-pass, $C_6$ to ground, a second tank circuit, $L_3C_1$, is connected. This tank circuit is important in the operation of the circuit. Without it, it would be impossible to obtain appreciable output at the second harmonic of the crystal. The constants of this circuit need not be changed when going from one frequency to another in a given band nor when changing from fundamental to harmonic operation with a given crystal.

The miniature lamp, $D_1$, connected in series with the crystal, serves as an indicator of crystal

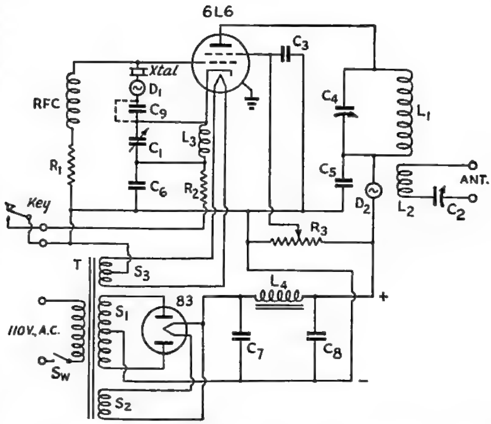



*Fig. 18* — **Circuit diagram used in both models of the transmitter.**

$C_1$ — Mica trimmer condenser (cathode tuning), 260-μμfd. max., (Hammarlund CTS-160). Two required; one mounted in each cathode-coil form (see text).
$C_2$ — Antenna tuning condenser — 250-μμfd. midget variable (National STH-250).
$C_3$ — Screen by-pass condenser, 0.01-μfd. paper (Mallory).
$C_4$ — Plate tank condenser — 250-μμfd. midget variable (National STH-250).
$C_5$ — Plate by-pass condenser, 0.01-μfd. paper (Mallory).
$C_6$ — Cathode by-pass condenser, 0.01-μfd. paper (Mallory).
$C_7$–$C_8$ — Filter condensers — 8-μfd. 600-volt-working electrolytic (Mallory HS692).
$C_9$ — 50-μμfd. mica (C-D).
$R_1$ — Grid leak, 20,000 ohms, 1 watt (IRC).
$R_2$ — Cathode biasing resistor, 200 ohms, 2 watts (Centralab).
$R_3$ — Screen voltage-divider resistor, 25,000 ohms, 50 watts with slider (Ohmite).
$D_1$ — 60-ma. dial light (r.f. crystal-current indicator).
$D_2$ — 60-ma. dial light (plate-current indicator).
RFC — R.f. choke, 2.5 mh. (National R100U).
$L_1$, $L_2$, $L_3$ (See coil table.)
$L_4$ — Filter choke, 30 henries, 80 ma., 350 ohms (Stancor C1420).
T — Multiple-winding power transformer. $S_1$ — 350 v. each side of center-tap, 120 ma.; $S_2$ — 5 v., 4 a.; $S_3$ — 6.3 v., 4.7 a. (Thordarson T-13R14).
$S_w$ — Single-pole single-throw toggle switch.
Three 6-prong sockets (Amphenol MIP).
One 4-prong socket (Amphenol MIP).
One 8-prong octal socket (Amphenol MIP).
Five (to cover all bands) 1½-inch diameter 6-prong coil forms (Hammarlund).
Two grommet-type sockets for indicator bulbs (miniature base).
Two bakelite shaft couplings (¼-inch hole, ¼-inch shaft).
Two dial scales, 3-inch diameter.
2 bar knobs, 2 inch.
Six polystyrene terminal strips (National FWB).
One Type 6L6 tube.
One Type 83 rectifier tube.
Wood for base or one 7 × 13 × 2-inch metal chassis.
One telegraph key.
Wire for coils and wiring, machine screws and nuts, wood screws, grommets, power cord, etc.

For the metal model, the only additional parts required are the pair of tip jacks for the key terminals and the 8 × 16 × 18-inch cabinet (Par-Metal CA202). Also required is one crystal for any two adjacent bands.

r.f. current. While a d.c. milliammeter with a 150-ma. scale is much to be preferred as an indicator of d.c. plate current, a similar lamp shown at $D_2$ will give a rough indication for tuning. If the meter is used, it should be of the type with an insulated adjusting screw. It may be mounted on the panel above and between the two dial plates and connected in place of $D_2$ with the positive terminal toward the power supply.

The condenser, $C_9$, is inserted in series with the crystal to limit crystal current to a value which will not subject the crystal to danger of fracture when a 7-Mc. crystal is used. This condenser is automatically short-circuited when the cathode coil ($L_3$) for a 3.5-Mc. crystal is plugged in.

The key is in series with the d.c. cathode circuit through $L_3$ and $R_2$ to ground. No r.f. flows through the key circuit, however, since $C_6$ by-passes it to ground. The purpose of $R_2$ is to provide grid bias for the 6L6 in case the tube is not oscillating and thereby prevent excessive plate current from flowing, which might result in damage to the tube. $R_2$ also aids the crystal to start oscillation because the small bias it provides reduces the loading effect of the tube on the crystal.

The screen grid of the tube is maintained at the correct d.c. voltage by adjustment of the tap on the voltage divider, $R_3$. The screen is by-passed for r.f. by $C_3$.

The coupling coil, $L_2$, and condenser, $C_2$, are for transferring the radio frequency power to the antenna. They will be discussed in detail in a later section.

## THE POWER SUPPLY

The power supply for the transmitter corresponds in purpose to the filament supply and "B" batteries used with the receiver. We could, in fact, use batteries with the transmitter, but since we need a larger tube for the transmitter and this tube takes relatively heavy filament and plate currents, the use of batteries would be uneconomical. For the transmitter, therefore, we

take the power from the 115-volt a.c. mains and change its voltage to suit the tube we are going to use.

The regulations governing amateur stations say that we must use only a power supply furnishing direct current for the plates of the tubes used in the transmitter. For this reason we cannot simply use a transformer to step up the voltage from the power line and put the alternating current directly on the tube plates; the stepped-up alternating current must be *rectified*, or changed to unidirectional current, and then *filtered* so that the pulsations in the rectified current will be smoothed out and the resulting current made similar to that provided by a "B" battery. To do this we use a circuit like that shown in the lower part of Fig. 18. A transformer, *T*, changes the voltage of the power line to values suitable for the transmitter by means of its secondary windings, marked $S_1$, $S_2$ and $S_3$ in Fig. 18. $S_1$ is the high-voltage secondary; the total voltage between the ends of this winding is 700 volts, and since the winding is tapped at the center we get 350 volts on each side of the center-tap. $S_2$ is a 5-volt winding which supplies power for heating the filament of the Type 83 rectifier tube, while $S_3$ is a 6.3-volt winding which furnishes power for the filament of the 6L6 tube in the transmitter. The outside ends of $S_1$ are connected to the plates of the rectifier tube; then as the ends of the winding alternately become positive during the a.c. cycle, current flows from the plates to the filament in the rectifier tube and is delivered to the filter, which consists of the condensers $C_7$ and $C_8$ and the choke coil, $L_4$. Since the rectifier tube will pass current only in one direction, from plate to filament, the current supplied to the filter is unidirectional, but its value is varying rapidly. These variations are smoothed out by $C_7$, $C_8$ and $L_4$, because both capacity and inductance possess the property of storing electrical energy; they function, in fact, in much the same way as the flywheel on a mechanical engine. Because of its inertia, the flywheel takes the pulsating power delivered by the engine from its cylinders and irons it out into a smooth rotary motion. The electrical filter takes the electrical pulsations from the rectifier and smooths them out into direct current. The power supply described here is quite similar to those used in modern broadcast receivers. It is, in fact, assembled almost entirely from parts used for that purpose and consequently is relatively inexpensive.

**DANGER—HIGH VOLTAGE**

**• It must be realized that the plate supply equipment of even a low-powered transmitter is a potential lethal machine. It is ever ready to deal out sudden death to the careless operator. A number of amateurs, indeed, have been killed by the output of their power supplies during the last few years. Many more have suffered severe injury. We cannot urge too strongly the observance of extreme care in the handling of power supplies and transmitters.**

## "BREADBOARD" LAYOUT AND CONSTRUCTION

The photographs show two versions of the same transmitter. One is constructed on a standard metal chassis which will fit a standard metal cabinet, if an enclosure is found desirable, while the other is built up on a homemade base of wood which some may find less difficult to work with than the metal. The wood base has the same outside dimensions as the metal chassis (7 × 13 × 2 inches) so that it may also fit the standard cabinet. A piece of ½-inch board 7 × 13 inches forms the top, which is supported by three pieces of "one-by-two" stock to which it is fastened with screws or finishing nails. The strip at the rear is set in about ⅜ inch, so that the terminals mounted on it will not be so exposed to accidental contact. The sockets in the row to the right (rear view) are centered on a line 1¼ inches from the edge. The cathode-coil socket (6-prong) is centered 1¾ inches, the 6L6 socket (8-prong octal) 3¾ inches and the crystal socket (6-prong) 5¾ inches from the rear edge of the base.

Before mounting the cathode-coil socket, Prongs 3 and 4 should be wired together and also Prongs 5 and 6, as indicated in Fig. 21. This serves to connect $C_1$ across $L_3$ when the coil is plugged in the socket. The prongs of the crystal socket should also be wired as shown in Fig. 21.

The two variable condensers are mounted, with machine screws up through from under the base, on National FWB Victron terminal strips, one on top and one underneath, on each side of the baseboard. These each require two ½-inch holes. The strips are centered 4⅛ inches from either end. The front hole for each comes 1¼ inches from the front edge. The socket for the plate tank coil (6-prong) is centered between the two variable condensers and 2¾ inches from the front edge. Before mounting the plate tank-coil socket, two ½-inch holes should be drilled through the baseboard under socket Prongs 3 and 6.

The placement of other components on top of the base may be judged from the photographs. A ½-inch hole should be drilled close to the inside edge of the transformer for the flexible terminal leads. A pair of small holes for the filter-choke leads and another pair for the leads to the plate-circuit indicator lamp will also be required. Each socket is mounted with tubular spacers 1 inch long and 1½-inch No. 6 wood screws. After the sockets have been mounted, holes should be

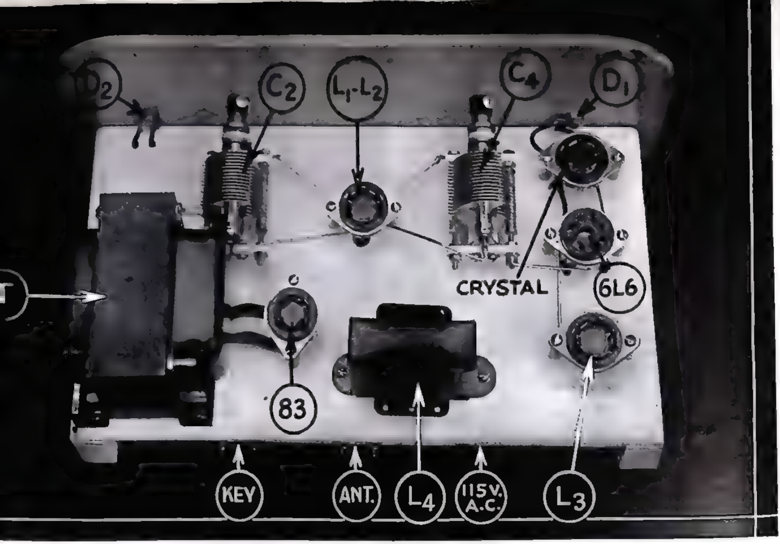



*Fig. 19* — **Rear view of the wood-base transmitter with coils and tubes removed to show placement of sockets.**

drilled with a No. 18 drill close to the following terminals (refer to sketches in Fig. 21): one filament terminal (F) of the rectifier socket; screen (SC), grid (G), shield (SH) and both heaters (H) of the 6L6 socket; Prong 4 of the cathode-coil socket.

Two ½-inch holes will be required at the middle of the rear supporting strip for the third pair of FWB terminal strips which serve as insulators for the antenna terminals. Two additional pairs of holes, one pair to either side of the antenna terminals, should be drilled for the No. 6 machine-screw terminals for the key and the 115-volt line input.

Underneath the base, the two filter condensers, the voltage-divider resistor, and the two lug strips are fastened with small wood screws. The r.f. choke is fastened to the side supporting strip with a machine screw through the strip.

In this case, the base was finished off with a few coats of white enamel, sandpapering between coats, to form a good photographic background. Almost any finish will do; shellac, varnish or clear Duco are often used for a natural finish.

The panel is cut from a piece of ¼-inch plywood and is 6 inches high by 14 inches long. Holes at least ½-inch in diameter should be cut for the insulated shaft extensions which are fitted to the variable-condenser shafts after the shafts have been cut off to a length of about ⅜ inch. Holes ⅜ inch in diameter should be drilled and then reamed out to fit the grommet-type indicator-bulb sockets. A half-inch hole will be required for the toggle switch and a woodscrew hole at each end of the panel is needed for fastening it to the base. It is a good idea to make all holes before finishing either base or panel. The dial plates are simply cemented to the panel with rubber or Duco cement.

The bakelite shaft extensions should be placed on the condenser shafts before the panel is put in place. After the panel is on, the bar-knob pointers should be set so that the pointer is at zero on the scale when the condenser is at minimum capacity (rotor plates all out).

### Wiring

The wiring underneath should be done first. (Refer to photograph showing bottom view of base.) The exact placement of the wire is not important except that it is a good idea to keep it flat against the base. The 6.3-volt heater wires for the 6L6 (green) run from the hole under the transformer along the rear to the first two lugs from the rear on the 4-lug strip. From these lugs, the wires are extended with push-back wire up through the base to the heater terminals (H) of the 6L6 socket. One of the 115-volt primary wires (small black) is run in between the filter condensers to one side of the toggle switch, leaving enough slack in the wire so that the switch may be mounted when the panel is fastened to the base. A wire is then run from the opposite side of the toggle switch to one of the 115-volt power-input terminals on the rear strip. The second 115-volt primary wire goes from the transformer

to the other power-input terminal.

A wire is connected to one of the filament terminals of the rectifier-tube socket and is then run down through the hole previously drilled to one lug of the small lug strip underneath. The nearest of the two filter choke ($L_4$) leads runs down through a hole and is connected to this same lug and the red (positive) wire of the first or input filter condenser ($C_7$) is also connected to the same point. The other wire from the filter choke runs down through the hole and is connected to the rear end of the voltage-divider resistance ($R_3$). The red wire from the second filter condenser ($C_8$) connects to the same point from where a wire is run along the rear edge to the left, thence along the left edge, up through the base to one side of the plate-circuit lamp ($D_2$), leaving enough slack for mounting. From the other side of the lamp, a wire goes down through the second hole to the soldering lug under the front-bracket mounting screw of the plate tank condenser ($C_4$).

The center-tap lead from the transformer high-voltage winding (red and yellow) goes along in between the two filter condensers to the front end of the voltage-divider resistor. The black wires (negative) of each of the filter condensers go to this same point. The center-tap wire of the transformer winding supplying the 6L6 heater (green and yellow) is also brought to the same point. A wire also runs from the front end of the resistor to the fourth lug of the longer lug strip.

One of the two key terminals is connected to the third lug of the long lug strip and the other to the fourth lug.

The grid-leak resistor ($R_1$) is soldered between the fourth lug and the top end of the r.f. choke (*RFC*). The other end of the r.f. choke is connected to the grid terminal (G) of the 6L6 socket by an insulated wire running up through the base.

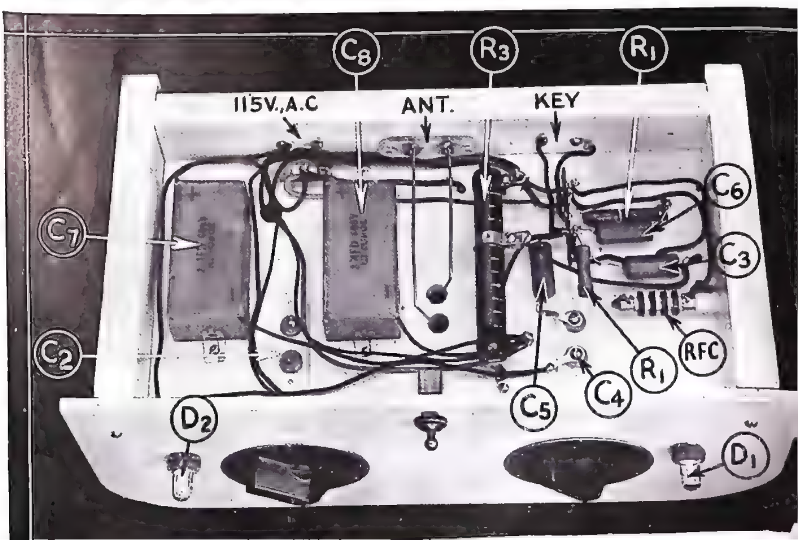
One end of the cathode resistor ($R_2$) is soldered to the third lug, while the other end is connected to Terminal 4 of the cathode-coil socket by means of an insulated wire running up through the base. The cathode by-pass condenser ($C_6$) connects between the fourth lug and the end of the cathode resistor going to the coil socket.

It will be noticed that one end of each by-pass condenser is marked "Ground." This end of the condenser should always be connected to the common ground wire.

One end of the screen by-pass condenser ($C_3$) is soldered to the fourth lug, while the other end is connected with an insulated wire through the base to the screen terminal (SC) of the 6L6 socket. The slider on the voltage-divider resistor is set midway between the fourth and fifth lines from the rear end and then a wire is soldered to the slider. This wire connects to the tube end of the screen by-pass. The plate by-pass ($C_5$) is connected between the fourth lug and the soldering lug under the rear mounting screw of the plate tank condenser. After a wire is run down through the base connecting the shield terminal (SH) of the 6L6 socket to the fourth lug, a pair of wires from Terminals 3 and 6 of the plate tank-coil socket, down through the large clearance holes to the antenna-output terminals, completes the wiring underneath the chassis. These last two wires should be kept well spaced from all other wiring beneath the baseboard.

On top of the base, most of the wiring is done with No. 14 bare wire. One wire connects ter-

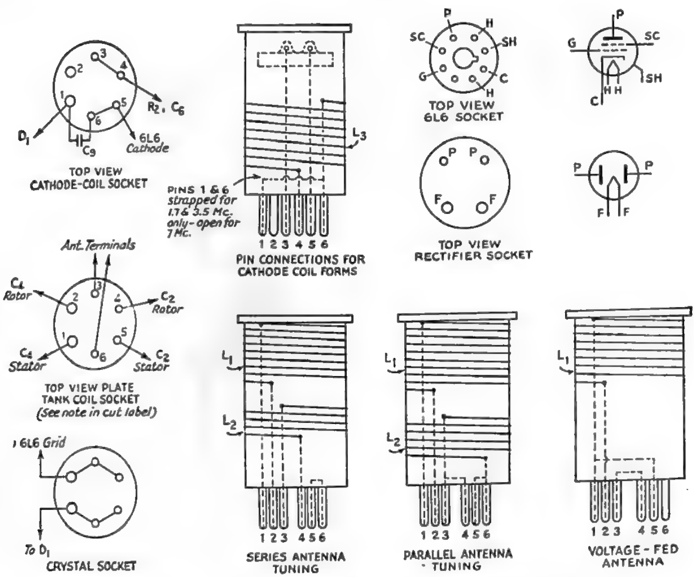
*Fig. 20* — Bottom view of the wood-base model showing the wiring and parts arrangement underneath.



minal No. 5 of the cathode-coil socket to the cathode terminal (C) of the 6L6 socket. A piece of insulated push-back wire connects Terminal 1 of the cathode-coil socket to one side of the crystal-current indicator lamp ($D_1$). The other side of $D_1$ is connected to one side of the crystal socket.

A short length of No. 14 wire connects the grid terminal (G) of the 6L6 socket to the other side of the crystal socket. A No. 14 wire connects the plate terminal (P) of the 6L6 socket to the stator of the plate tank condenser at the rear, while another connects the same stator at the front to Terminal 1 of the plate tank-coil socket. The rotor connects to Terminal 2. Terminals 4 and 5 of this socket connect respectively to the rotor and stator of the antenna tuning condenser, $C_2$.

The rectifier-filament leads (yellow) from the transformer each connect to one of the two filament terminals of the rectifier tube socket, while each of the two high-voltage transformer secondary wires (red) connects to one of the plate terminals of the rectifier-tube socket. Soldering the small mica condenser, $C_9$, between Terminals 1 and 6 of the cathode-coil socket completes the wiring.




*Pin connections for Plate Tank-Coil Forms for wood-base Model. (Reverse all connections to pins 1&2 for metal model)*

*Fig. 21* — Transmitter tube, socket and coil connections. In the metal version, connections to the tank-coil socket are reversed. Prong 1 goes to rotor of $C_4$, Prong 2 to the stator of $C_4$, Prong 4 to the stator of $C_2$ and Prong 5 to the rotor of $C_2$. This requires reversing coil connections as mentioned in the drawing.

$L_1$ — 3.5 Mc. — 22 turns No. 22 d.s.c., 1½ inch diameter, 1 inch long.
7 Mc. — 12 turns No. 22 d.s.c., ½ inch diameter, 1 inch long.
14 Mc. — 9 turns No. 18 enameled, 1½ inch diameter, 1 inch long.

$L_2$ — *Parallel Tuning*
3.5 Mc. — 20 turns No. 22 d.s.c., close-wound.
7 Mc. — 7 turns No. 22 d.s.c., close-wound.
14 Mc. — 4 turns No. 22 d.s.c., close-wound.

$L_2$ — *Series Tuning*
3.5 Mc. — 10 turns No. 22 d.s.c., close-wound.
7 Mc. — 8 turns No. 22 d.s.c., close-wound.
14 Mc. — 5 turns No. 22 d.s.c., close-wound.

$L_3$ — 3.5-Mc. crystals — 10½ turns No. 22 d.s.c., 1½ inch diameter, 1 inch long.
7-Mc. crystals — 6½ turns No. 22 d.s.c., 1½ inch diameter, 1 inch long.

## COILS

The coils are wound on Hammarlund 1½-inch diameter 6-prong coil forms. Dimensions are given under Fig. 21. Since the length of the winding is given in each case, the wire holes may be drilled in the form with a small-size drill before the winding is started. The cathode coil winding ($L_3$) should be made near the bottom of the form while the plate tank coil winding ($L_1$) is made near the top of the form. The wire holes should be drilled above and roughly in line with the pins to which the wires passing through will be soldered.

Most of the windings require spacing of the turns to fill out the required length on the form. This may be done by trial or by winding the required number of turns close together and then spacing the turns out after the winding has been completed. The windings should be kept tight at all times. Several inches of wire should be left at the ends inside the form so that they may be pulled out through the open end of the form. The insulation may then be removed from these ends up to a point near the inside wall of the form and the bare ends fished down through the appropriate pins (Fig. 21) and pulled taut. The wires are then soldered to the pins and the excess length cut off. In cases where strapping of pins together is required, a strap is made by forming a hairpin-shaped piece of bare wire, fishing the ends down through the pins to be connected together, pulling tight and soldering. If a coil connection is to be made to the same pin, both wires should be passed through the pin before soldering, of course.

Each cathode coil requires a mica trimmer condenser ($C_1$). It will be noticed that the condenser specified has a double terminal on one side; the sections should be soldered together and a wire 6 or 7 inches long soldered to each terminal. The insulation should be removed from these wires up to within an inch or so of the condenser and then pulled out straight. The wires may then be fished down through the appropriate pins and pulled tight as described previously. If desired, the condenser may be fastened with a 4-36 machine screw to the step inside the coil form after the mounting hole in the condenser has been drilled out to pass the screw.

Information on winding and connecting the antenna winding, $L_2$, will be given later.

## METAL CONSTRUCTION

While it is, of course, possible with the metal chassis to follow almost exactly the method of assembly used with the wood base and, therefore, avoid cutting large holes in the metal, a much cleaner and more permanent appearing job results if the sockets are submounted. This permits most of the wiring to be placed out of sight underneath the chassis.

The socket holes are most easily cut with a socket-hole punch. One of the best types is the Greenlee punch which is operated with a wrench. It requires the drilling of a ⅜-inch hole at the hole center. An adjustable circle cutter operated with a carpenter's brace may also be used. Although somewhat more tedious, it is also possible to mark out the hole with a compass and then drill a series of closely-spaced holes inside the line. The center may then be knocked out with a hammer and cold chisel and the hole smoothed up with a file.

Frequent reference should be made to the constructional details given for the wood model.

Parts on top of the chassis, as well as the sub-mounted sockets are placed in positions identical to those described for the first model. The chief difference in component arrangement is in the positions of the filter condensers and the four-lug terminal strip, the latter being moved over near the rectifier socket and small terminal strip. The filter condensers should be placed in positions which will not interfere with the transformer mounting screws. Half-inch holes are required between the cathode-coil and 6L6 sockets and near the rear stator terminals of each of the variable condensers. Each of these holes is lined with a rubber grommet to prevent accidental short-circuit of the wires to the chassis. A ½-inch hole is also required in the front edge of the chassis for the toggle switch. A pair of inexpensive insulated phone-tip jacks is substituted for the machine-screw terminals for the key. The power-input cord runs through a single grommeted hole in the rear edge. The indicator lamps must, of course, be insulated from the metal panel. Therefore, ½-inch holes are drilled in the panel and the grommets set in these holes to provide the necessary insulation. A pair of ¼-inch clearance holes immediately in front of the crystal socket is required for the leads to $D_1$.

#### Wiring

Since the chassis itself is a conductor, the common ground wire used in the first model is unnecessary, parts which require grounding being connected to the chassis at the nearest convenient point. Care should be taken to make sure that good electrical contact is made with the chassis, scraping a small area of the paint finish where necessary.

All power wiring is done first. Reference should be made to the more detailed wiring description given earlier if any uncertainty arises.

The rectifier plate (red) and filament (yellow) leads from the transformer go to the rectifier socket terminals. The 6L6 heater wires (green) go to the first two lugs from the top of the long lug strip, thence to the tube prongs (H). The 115-volt cord connects to the two insulated terminals of the short lug strip. The center-tap of the high-voltage winding (red and yellow) and the center-tap of the

6L6 heater winding from the transformer (green and yellow) connect to the chassis at the lug-strip mounting screw. The red positive lead of the first filter condenser ($C_7$) toward the top goes to the third lug (from the top) of the long terminal strip, while that of the second filter condenser ($C_8$) goes to the last or bottom lug. A short piece of wire connects one of the rectifier-socket filament terminals to the third lug. A wire runs from the bottom lug to the bottom end of the voltage-divider resistor ($R_3$), while a second wire runs from the bottom lug around the right-hand end of the chassis and up through one of the holes to one side of $D_2$. From the other side of $D_2$, a wire runs along the top edge of the chassis to the top soldering lug under the mounting screw for $C_4$, to the left.

The nearest of the filter choke ($L_4$) leads goes to the third lug of the long strip, while the other choke wire goes to the bottom end of the voltage-divider resistor. The two black wires from the filter condensers are connected to a soldering lug under one of the transformer mounting screws.

Of the two transformer primary wires (small black), one goes to one side of the toggle switch while the other goes to one of the lugs to which the 115-volt cord is connected. The other side of the toggle switch goes to the second 115-volt lug.

Over to the left, one of the key terminals is grounded to a soldering lug under one of the filter choke mounting screws. One end of $R_2$ is soldered to the other key terminal, while the opposite end of $R_2$ is soldered to Terminal 3 of the cathode-coil socket. One end of the by-pass, $C_6$, connects to the same socket terminal, the other end being grounded to a soldering lug under the socket mounting screw. The mica condenser, $C_9$, is soldered directly across Terminals 1 and 6 of the cathode-coil socket. The screen by-pass, $C_3$, is placed along the end of the chassis, being connected with one end to the screen terminal of the 6L6 socket and the other end grounded at the cathode-coil socket mounting screw. The plate by-pass, $C_5$, is between the crystal socket and the plate tank-condenser mounting strip with one end connected to a lug under one of the variable-condenser mounting screws and the other end grounded to the nearest socket mounting screw. The left-hand end of the r.f. choke goes to the grid terminal of the 6L6 socket. The outer end is soldered to one end of the grid leak, $R_1$, whose opposite end is grounded at the socket mounting screw. A wire connects the slider on the voltage-divider resistance (set between the fourth and fifth marks from the bottom end) and the screen terminal of the 6L6 socket. The top end of this resistance is grounded to the mounting screw.

A piece of push-back wire goes from one side of the crystal socket up through the hole in the chassis to one side of $D_1$. From the other side of $D_1$ a wire runs back down through the chassis to Terminal 1 of the cathode-coil socket. A short wire connects grid terminal (G) to the other side of the crystal.

The remaining wiring is done with bare No. 14 wire well spaced from the chassis. Terminal 5 of

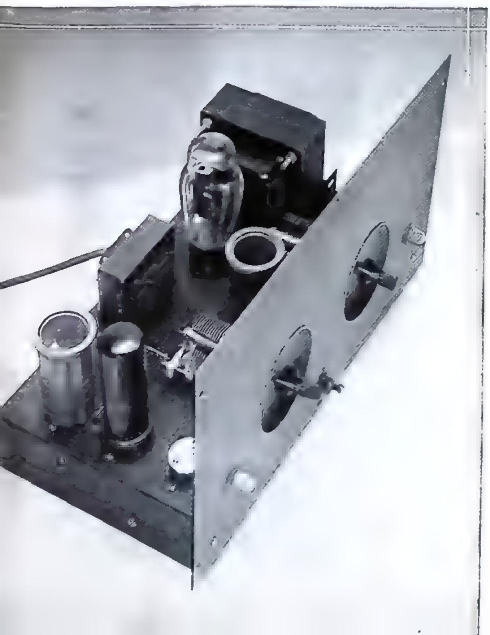


*Fig. 22* — Front view of the metal model of the simple transmitter with all coils and tubes in place.

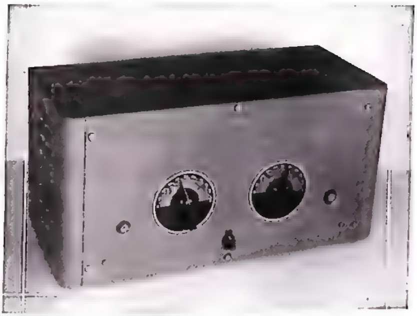


*Fig. 23* — The metal model complete in its cabinet.

the cathode-coil socket is connected to the cathode terminal of the 6L6 socket. A wire connecting the plate terminal of the 6L6 socket and the stator of the plate tank condenser passes up through the grommeted hole between the two sockets. Short, direct wires connect Terminals 1 and 5 of the plate tank-coil socket respectively to the mounting screws of the plate tank condenser and the antenna tuning condenser. Similarly, wires are formed to pass through the grommeted holes to the rear of the variable condensers, connecting the stators of $C_1$ and $C_2$ respectively with Terminals 2 and 4 of the plate tank-coil socket. Two longer direct wires connect Terminals 3 and 6 of the coil socket to the antenna output terminals at the rear.

Spacers should be used between the panel and the chassis to leave space for the upturned lower edge of the cabinet opening. The mounting screws and spacers should clear this upturned edge. Panel holes are drilled and the dial plates are cemented to the panel as described previously.

## TESTING

After checking carefully the wiring to make certain that no mistakes have been made, turn the toggle switch to the "Off" position. Connect the 115-volt cord to the proper terminals at the rear, if the wood base is used, and a telegraph key across the key terminals. If the pin jacks are used, the keying leads may be fitted with phone tips or the bare ends of the wire may be inserted in the jacks. The "arm" of the key should be connected to the key terminal opposite that to which $R_2$ connects.

Place the 6L6 and 83 tubes in their respective sockets. Plug in a crystal and cathode coil, making sure that the latter is the one designed for the band in which the *crystal* frequency lies. The plate tank coil to be first used should be one which tunes to the band of the crystal frequency. Place 60-ma. dial lights in the indicator sockets.

The 115-volt cord may now be plugged into a convenient outlet and the toggle switch turned to the "On" position, after which the metal parts of the tank condenser or other exposed parts or wiring should not be touched, since there is danger of severe shock. The rectifier filament should immediately light up and, in a few seconds, a blue glow should appear inside the rectifier plates. If either fails to develop, power should be turned off. A piece of heavily insulated wire, bare at the tips, should be used to short-circuit momentarily each of the filter condensers to guard against any danger of a discharge should it happen that the voltage divider resistor is defective or has not been connected correctly. The power-supply wiring should be checked.

With the power supply working properly, 15 to 30 seconds should be allowed for the 6L6 heater to reach operating temperature. The envelope of the 6L6 should feel warm to the touch. Turn the adjusting screw of the cathode tuning condenser clockwise to the limit. The adjusting screw should then be backed off about ½ turn for the 3.5-Mc. coil and 1 turn for the 7-Mc. coil. Set the tank condenser, $C_2$, at mid-scale for 3.5 Mc. or at minimum capacity (zero on dial) for 7 Mc.

Upon closing the key, the plate-current indicator lamp should light up to full brilliance (60 to 80 ma.), while the crystal indicator lamp should glow rather dimly. The plate tank condenser should now be turned slowly toward maximum capacity (100 on dial). At some point within the range of the condenser, $D_2$ should start to dim, while $D_1$ will gradually increase in brightness until it attains a maximum just before resonance is reached. This maximum will be greatest with a 7-Mc. crystal. Should $D_1$ burn out, it is an indication that the screen voltage is too high and the slider on the voltage-divider resistor should be moved slightly further away from the bottom end.

At exact resonance, $D_1$ should show a dip in crystal current, glowing dimly with low-frequency crystals but more brightly with 7-Mc. crystals. Simultaneously, $D_2$ should dip out or to a dim glow (10 to 30 ma.). As the setting of the condenser is increased very slightly, the crystal will stop oscillating. This will be indicated by $D_1$ suddenly going out and $D_2$ lighting up to full brilliance (60 to 80 ma.). As the capacity of the condenser is increased toward maximum, oscillation will resume, $D_2$ running bright (60 to 80 ma.), while $D_1$ shows a dim or medium glow.

Now, plug in a plate tank coil which tunes to the second harmonic of the crystal frequency.

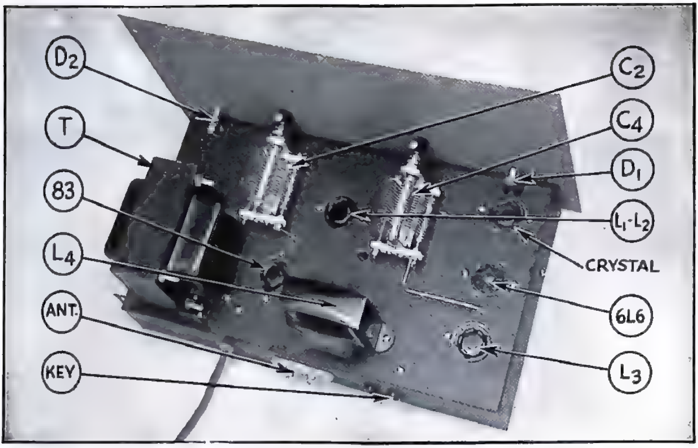



*Fig. 24* — Rear view of metal model of the transmitter with the coils and tubes removed.

Again, starting with the tank condenser at minimum capacity for 7- or 14-Mc. output and at mid-scale for 3.5 Mc., repeat the tuning process. The results should be similar, except that $D_1$ should not glow so brightly and oscillation will not cease when resonance is reached as indicated by a dip in $D_2$.

When using a 3.5-Mc. crystal with the 3.5-Mc. coil in the plate circuit it may be noticed that a second dip will be found below mid-scale on $C_2$. This indicates resonance at the second harmonic (7 Mc.). While this combination could be used for output at 7 Mc., the coil specified for 7-Mc. output will give better results, since the latter resonates with a higher capacity which helps to prevent unwanted harmonic radiation. When using a 7-Mc. crystal with the 14-Mc. coil, a second resonance point may be found near maximum

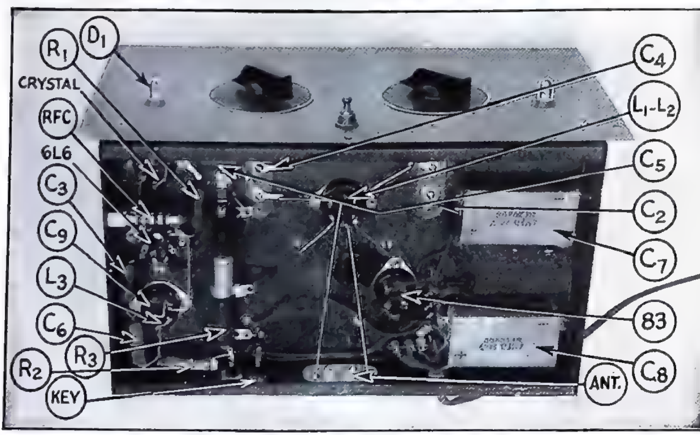



*Fig. 25* — Bottom view of the metal model showing placement and wiring of parts underneath.

capacity. This represents resonance at the crystal fundamental (7 Mc.) but greater efficiency will be obtained by using the 7-Mc. coil for 7-Mc. output. In all cases care should be taken to select the right point, as described above, for the desired output frequency.

When the transmitter is operating correctly as described above, it is ready for connection to the antenna. Before proceeding with the antenna-tuning process, however, it is necessary to decide what type of antenna we are going to use and in which bands we are going to work.

## THE ANTENNA

In most cases, the lowest frequency band at which it is desired to operate, the available space and the locations of suitable supports for the antenna will dictate the size and type of the antenna system. Four types are shown in the diagrams of Fig. 26, with the dimensions for various bands given in the table on this page.

### The Simple Voltage-Fed Antenna

At A is shown the simple voltage-fed antenna. The entire length of wire from the transmitter output terminal to the far insulator forms the radiating antenna. While it is simple and requires less space than some other types, it has the disadvantage that it is impossible to avoid bringing the radiating portion at the transmitter end near objects which may absorb energy. Nevertheless it finds frequent application, especially in cases where the transmitter is located above the ground floor where feeders of reasonable length cannot conveniently be used and where it is possible to run the antenna in an essentially straight line.

At B is shown the Marconi antenna in which good contact with the earth is essential. Although the total length of the antenna need be only half that of the voltage-fed antenna, the ground connection requires that a relatively large proportion of the antenna be at a low height. While the other antennas under discussion will work well at even harmonics of the fundamental frequency for which they are cut, making them useful for more than one band, this is not true of the Marconi type. It is used principally where space for a low-frequency antenna is limited. In such cases it may be used with the ground connection at the fundamental frequency only and, by disconnecting the ground, operated as a voltage-fed antenna as previously discussed at the harmonic frequencies.

C and D show antenna systems composed of two parts. The radiating portion, or antenna proper, may be placed in a favorable position with little regard for the location of the transmitter, to which it is connected by a *transmission line* or *feeders*. The close spacing of the feeder wires prevents appreciable radiation and, therefore, absorption from near-by objects is minimized. These systems are popularly known as "Zepp" antennas. The feeders may be attached either at one end of the antenna or inserted at the center. While it is possible to maintain a better balance in the system over a wide range of frequencies with the center-fed system, the location of the transmitter in relation to the antenna sometimes makes the end-fed arrangement more convenient.

### Antenna Dimensions

In the accompanying table dimensions are given for antennas and feeders for the various amateur bands. It will be noted that, with the exception of the Marconi type, the longer antennas may be operated on harmonic frequencies as well as the fundamental frequency. It should be understood that the power output of the transmitter itself must, of course, be at the desired frequency of operation. For example, if it is desired to operate a 3.5-Mc. antenna at 7 Mc., the output of the transmitter must be at 7 Mc.

**ANTENNA TABLE**

***Voltage-Fed Antenna***

| | |
|---|---|
| 3.5 Mc.<br>7 Mc.<br>14 Mc. | 130 ft. total |
| 7 Mc.<br>14 Mc. | 65 ft. total |
| 14 Mc. | 32.5 ft. total |

***Marconi Antenna (Grounded)***

| | |
|---|---|
| 3.5 Mc. | 65 ft. total |
| 7 Mc. | 32 ft. total |
| 14 Mc. | 16 ft. total |

***End-Fed Zepp***

| *Antenna Tuning* | *Antenna Length* | *Feeder Length* |
|---|---|---|
| 3.5 Mc. — series<br>7 Mc. — parallel<br>14 Mc. — parallel | 136 | 67 |
| 7 Mc. — series<br>14 Mc. — parallel | 67 | 33 |
| 14 Mc. — parallel | 33 | 33 |

***Center-Fed Antenna***

| *Antenna Tuning* | *Antenna Length* | *Feeder Length* |
|---|---|---|
| 3.5 Mc. — parallel<br>7 Mc. — parallel<br>14 Mc. — parallel | 136 | 67 |
| 3.5 Mc. — parallel<br>7 Mc. — series<br>14 Mc. — series | 100 | 38 |
| 3.5 Mc. — series<br>7 Mc. — parallel<br>14 Mc. — parallel | 67 | 34 |
| 7 Mc. — parallel<br>14 Mc. — parallel | 50 | 43 |
| 7 Mc. — parallel<br>14 Mc. — parallel | 33 | 51 |
| 7 Mc. — parallel<br>14 Mc. — series | 33 | 31 |

With the voltage-fed antenna, the lengths given are the over-all distance from the far end to the transmitter terminal. The same is true of the Marconi antenna.

With the end-fed "Zepp" type, the lengths given in the table are for the distances between the two antenna insulators as indicated by dimension "A," while the lengths given in the table for the center-fed antenna are the *sum* of dimensions "B" and "C" shown in Fig. 26-D.

The table also gives the feeder lengths which should be adhered to in order that power may be readily transferred to the system. The lengths given are for each feeder wire. The method of tuning (series or parallel) is also specified.

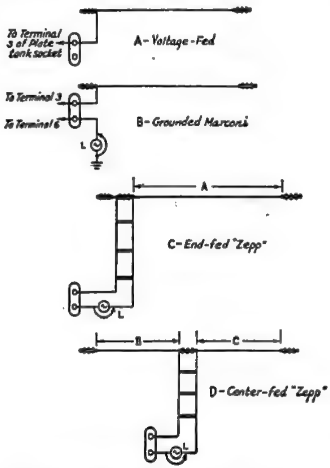



*Fig. 26* — Simple antenna systems recommended for use with the beginner's transmitter. Suitable dimensions are given in the table on the preceding page.

### Antenna Construction

It is always desirable to have the antenna, or at least as much of it as is possible, well up in the air and as far away from trees and buildings as the location will permit. An average height of 30 to 50 feet is desirable; the higher the better. Also, the antenna should run in a straight line if sufficient space is available. Nevertheless, if space is restricted it is better to use the full length, with a bend or two as necessary, rather than to shorten the dimensions given in the table. Measurement to the fraction of an inch is not important, however.

No. 14 or 12 enameled wire (not hard drawn) is suitable for the antenna and feeders and is easy to handle. No. 12 should be used for the longer antennas or where trees are used to support the antenna. No. 14 is suitable for feeders and short antennas with steady supports.

Almost any of the insulators offered for sale for antenna use are suitable for low- and medium-power transmitters. Losses will not be appreciable even with the glass insulators found in 5 & 10 cent stores. The use of somewhat larger insulators is advisable if the antenna is to be supported by trees, however, for in this case the insulators may be subject to severe mechanical strain. Six-inch feeder-spreader insulators are available in a number of types. Homemade insulators of glass tubing or sections of wood dowel thoroughly boiled in paraffin may also be used. The spreader insulators should be spaced along the feeders about every 5 to 10 feet, depending upon how tight it is possible to pull the feeders.

The feeders should not be doubled back sharply parallel to or close to any appreciable portion of the antenna. It is also well to avoid sharp abrupt bends in the feeders themselves. However, it is all right to double the feeders back under the antenna in a long sweeping curve which keeps the feeders and antenna well separated.

It is usually advisable to anchor the antenna or feeders with antenna insulators to the window casing, to prevent strains being transmitted to the transmitter itself. The antenna or feeders may then be passed through feed-through insulators set in a wood strip inserted over the top section or under the lower section of a convenient window.

### Ground Connection for Marconi Antenna

To provide a ground connection for the Marconi antenna a lead may be run to the water piping, providing the total lead to ground, including the length of the pipe before it enters the ground, does not exceed 20 feet or so. The pipe should be scraped clean and the connection made with a standard ground clamp. If an outside ground is to be used, it may be made by driving a metal rod into the earth to as great a depth as possible. The rod should be at least three or four feet long; greater length is desirable. Such a ground connection should always be made in naturally moist soil, because the resistance of very dry soil is too great to allow the ground to be effective. The lead to the ground connection should, of course, be kept as short as possible.

## ANTENNA COUPLING

IN ORDER to transfer energy from the transmitter to the antenna system, the two circuits must be coupled. An *inductively coupled* system is one in which an inductance forms the coupling element, while a *capacitively coupled* system is one in which a capacity forms the coupling element.

In order that the antenna system may take power readily, it is necessary that the system be tuned to resonance at the operating frequency. In Fig. 27 C and B, $C_2$ is the variable element provided for tuning the antenna system. When the condenser is connected in series with the

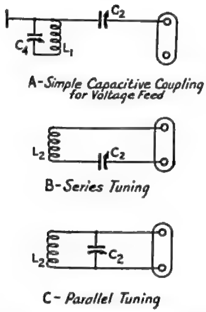



*Fig. 27* — Antenna coupling and tuning circuits. The proper connections for each system are made when the transmitter plate tank-coil form is plugged in by connecting the pins properly as shown in Fig. 21.

coupling coil, $L_2$, the system is called a *series tuned* system; when it is connected in parallel with the coil, the system is *parallel tuned.*

In the capacitively coupled system of Fig. 27-A no provision is made for tuning the antenna, and therefore the antenna length is more critical. Small discrepancies in length can be compensated for by tuning of the plate tank circuit, $L_1C_4$. This type coupling system is used with the voltage-fed antenna only.

Provision has been made in the transmitter for automatically setting up the proper series or parallel connection when the plate tank-coil form is plugged in, the wiring to the pins being so arranged. These connections are shown in Fig. 21.

# CHOOSING FREQUENCIES

By the time you have completed the transmitter, you will have had an opportunity to form some idea of the performance to be expected on the various amateur bands by listening with the receiver. You will have observed that, while greater distances are to be covered on the higher frequencies, conditions from day to day are more erratic. You will also have noted that extended ranges are possible on the lower frequencies only at night while the higher frequencies are usually at their best during the hours of daylight, in certain seasons becoming useless after nightfall. By consulting the table of antenna dimensions, you will see that the lower frequencies require a longer antenna than those for the higher frequencies only. From these considerations, you should have no great difficulty in deciding upon the frequency in which you will start your operation.

If you are like most amateurs, you will want to start operation in a band where there is plenty of activity and where conditions are generally satisfactory. In this case, operation in the 3.5- and 7-Mc. bands is the logical choice.

A suitable antenna system may be selected by a study of the advantages and disadvantages as set forth above and with consideration for the available space. The crystal should be ground for a frequency between 3500 and 3650 kc. if use is to be made of its second harmonic for operation in the 7-Mc. band, since the high-frequency limit of this band is 7300 kc. For 7- and 14-Mc. operation, the crystal frequency should fall between 7000 and 7200 kc., so that the second harmonic will not fall outside the limits of the 14-Mc. band.

It is advisable not to operate too close to the edges of the bands, to avoid any possibility of off-frequency operation resulting from a change in the crystal frequency because of heating or other causes. From this consideration, crystals of the low-drift type are preferable since their frequencies are essentially constant with changes in temperature. Crystals of this type also will operate safely with higher r.f. currents than will the ordinary X-cut type. A crystal of good quality is always to be recommended.

In choosing a crystal it is also advisable to avoid frequencies, either fundamental or second harmonic, that fall inside the sub-bands in which 'phone operation is permitted. At the time this booklet is being published the 'phone sub-bands have not been finally determined; also, it is expected that initially the 7- and 14-Mc. bands will not be restored in their entirety for amateur operation, but that several months may be required before the military services now occupying portions of those bands can be shifted to new frequencies. Before going on the air you should check with your local radio club or with ARRL, West Hartford 7, Conn., for the current frequency assignments.

### Coupling to the Antenna

With the transmitter working satisfactorily and the antenna erected, we are now ready to couple the antenna to the transmitter.

First the method of antenna tuning (series or parallel) required for the particular antenna in use and the band in which we are going to operate should be determined from the table of antenna dimensions. The straps may then be put in place in the coil forms as shown in Fig. 21. For series tuning, Pins 5 and 6 will be connected together; with parallel tuning, Pin 5 will be con-

nected to Pin 6 and Pin 3 to Pin 4. (Note the changes required for the metal model, Fig. 21.)

While it is difficult to make exact specifications for $L_2$, the dimensions given under Fig. 21 will serve as a guide. The required number of turns should be wound near the bottom of the plate tank-coil form.

With the antenna connected, the transmitter operating at the crystal fundamental, and the antenna tuning condenser, $C_2$, set at maximum capacity, tune $C_4$ for resonance as before. $C_4$ should not be set exactly at the capacity where $D_2$ glows dimmest but slightly below this point. $C_2$ should then be turned slowly toward minimum capacity while $D_2$ is watched closely. As $C_2$ approaches resonance in the antenna circuit, $D_2$ will become brighter. As soon as $D_2$ is almost up to full brilliance, $C_4$ should be readjusted for a dip in $D_2$. This dip will now be less pronounced. If the crystal stops oscillating at the exact dip, $C_4$ should be turned to a slightly lower capacity. The described process of adjusting $C_2$ and $C_4$ may be repeated until there is only a slight dip in $D_2$ as $C_4$ is tuned through resonance. $C_4$ should always be used for the final adjustment. If no indication of loading is obtained the coil-form connections should be checked; if they are found to be correct, the number of turns in $L_2$ should be altered.

A check should now be made on the keying by listening on the receiver with the receiving antenna disconnected and the receiver well removed from the transmitter. The 1.7-Mc. receiving coil should be used to listen for the signal; a harmonic of the oscillating detector is responsible for the signal heard. This prevents blocking of the receiver, which would occur if the receiver were tuned to the same band as the transmitter.

If the transmitter does not respond to keying or the keying is chirpy, the capacity setting of $C_4$ should be reduced slightly until good keying characteristics are obtained.

To obtain maximum output on the fundamental some sort of r.f. output indicator is required. A thermoammeter with a scale of 1 ampere is desirable, but a cheap and quite satisfactory substitute is a 60-ma. dial light similar to those used in the panel of the transmitter. The insulation of one of the feeder wires should be removed between the transmitter and the feed-through insulator at the window where the feeders enter, and the dial light should be connected in series with this feeder, as shown in Fig. 26. A strap of insulated wire two or three feet long should be shunted around the lamp as shown. One end of the shunt wire should be connected to the antenna output terminal and a clip placed at the other end. This clip should be attached to the opposite terminal of the lamp. Now, with the transmitter running and loaded as previously described, move the clip along the feeder away from the lamp a little at a time until the lamp shows a dim glow. If parallel tuning is used it may be necessary to remove the shunting wire entirely. $C_4$ and $C_2$ should then be adjusted alternately until the lamp lights the brightest.

When the transmitter is tuned to the second harmonic of the crystal in use, the same process is followed. At the harmonic frequency there should be no danger of the crystal ceasing oscillation at exact resonance and no critical adjustment for good keying should be required. With the transmitter tuned for maximum output, the cathode tuning condenser should be given a final check by readjusting for maximum output at the harmonic. Thereafter no further adjustment should be required.

A similar process is followed in coupling to the Marconi antenna. The coupling coil should have approximately the dimensions given in the antenna table on page 33 for series tuning.

Coupling to the voltage-fed antenna is somewhat simpler in that no coupling coil is required. The blocking condenser, $C_2$, is simply connected in series with the antenna and the top end of $L_1$. This connection is made by connecting Pin 3 to Pin 4 and Pin 1 to Pin 5 on the plate tank-coil form, as indicated in Fig. 21. (Note changes for metal model.) Now start the transmitter and set $C_2$ to minimum capacity. Tune $C_4$ to resonance, where $D_2$ will dim to an extent depending upon the loading. If the dip is pronounced, increase the setting of $C_2$ bit by bit until there is only a slight dip in $D_2$ as $C_4$ is tuned through resonance. If no dip can be found, or if the crystal ceases oscillation reasonably close to resonance even with $C_2$ at minimum capacity, the circuit is loaded too heavily. This is most likely to occur with a 7-Mc. crystal operating at the fundamental. In this case it will be necessary to remove the connection between Pins 1 and 5, connect a lead to Pin 5, and bring it out the open end of the coil form. Scrape the insulation off a spot on each of the top 3 or 4 turns of $L_1$ and touch the end of the loose wire to various turns until one is found which permits proper control of the loading. Do not hold the lead in your hand while the toggle switch is on, but let it rest on the bare turn. Once the proper turn has been found, the tap may be soldered in place.

## INTERFERENCE WITH BROADCASTING

IT SOMETIMES happens that the operation of a transmitter, even one of low power such as is described in this booklet, will cause interference with neighboring broadcast receivers. Such interference usually takes the form of "clicks" or "thumps" heard on the affected broadcast receiver every time the key is pressed. There are many ways of preventing such interference. One of the simplest is shown in Fig. 28.

An iron-core coil is connected in series with the key and a condenser and resistor across the key terminals. The coil may be an audio choke of about 5 henrys inductance or the primary of a small transformer; the primary of a cheap bell-ringing transformer often is very effective. The size of the condenser is not critical — 0.5 or 1 μfd. usually is about right. The resistor is used to minimize sparking at the key contacts; generally 100 ohms is sufficient, but it is advantageous to use a variable unit with a maximum resistance of about 500 ohms so that the most effective operating value can be chosen readily. A combination such as this, known as a "key-thump filter," usually works best when it is inserted right at the transmitting key itself rather than near the transmitter terminals, especially when the key is located several feet from the transmitter.

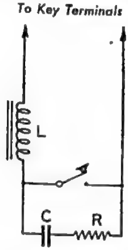



*Fig. 28* — A key-thump filter to prevent interference with broadcast reception.

## ARRANGING THE STATION

It is helpful to arrange the station neatly and to keep paper, pencils, callbooks, etc., where they are always handy. Furthermore, it is as easy to make a shipshape job of the station as to have it look "haywire." You do not want to have to apologize for the appearance of your equipment.

Since the antenna lead-ins usually are brought into the house through a window, it is a good idea to have your operating table located near a window which is convenient for this purpose. The receiver and transmitter should not be too close to each other.

A good method of bringing the antenna wires into the station is to cut a board about 4 inches wide and the same length as the width of the window. Through this board may be run small porcelain insulating tubes of the type used in house wiring, the transmitting antenna wire coming through one (or a pair of them if the Zepp antenna is used) and the receiving antenna wire through another. The board should be placed in the window frame and the sash closed down tight upon it. The lead-in wires then will be fairly well insulated even in wet weather, and the window can be kept tightly shut.

The porcelain tubes, incidentally, should be run through the board at a slight downward slant (with the "down" end on the outside) to prevent rain water from running down the antenna wires and into the house.

The transmitting antenna may also be used for receiving if desired. Changing over from receiving to transmitting may be accomplished by the use of a small porcelain-base single-pole double-throw switch. The antenna is connected to the blade of the switch, the antenna post on the receiver to one of the switch jaws, and the antenna post on the transmitter to the other switch jaw. The ground connection need not be changed over, although you may do so if you wish.

A lightning arrester cannot be used on the transmitting antenna since it would allow a considerable portion of the energy of the transmitter to leak off. A switch is necessary, therefore. A single-pole double-throw lightning switch is best, but one of the same type as used for the antenna change-over switch will serve. The switch should be screwed to the window frame at the point where the transmitting antenna enters the room. The blade terminal on the switch is connected to the antenna; one of the jaw terminals leads to the antenna post on the set, and the other leads to a ground connection.

## LICENSES

As we have said before, you must have a government license before you can go on the air with your transmitter. The amateur license is really two licenses in one: one for the station, the other a personal amateur operator license. Both are required by law, and are issued by the Federal Communications Commission. The license costs nothing, but, in the case of the operator portion, requires some study of elementary theory and the U. S. radio laws and regulations as they apply to amateur stations. This knowledge is not difficult to acquire, however, and if you start to study at about the same time you start construction of the station, you should be adequately prepared by the time the station is finished.

At this point we may say that only citizens of the United States are eligible for either station or operator licenses. In addition, a station license will not be issued, even to a citizen, if the transmitter is to be located on property which is controlled by an alien.

The station portion of the license is your station's official "registration"; it licenses your transmitter for operation in the amateur bands and designates the call to be used. It is issued after filling out a form provided for the purpose — no examination is given in connection with it.

However, station authorizations are issued only to persons who also qualify for operator licenses.

The operator portion of the license is your personal authorization to operate an amateur station — not only your own station but any amateur station. You may in fact obtain just an operator's license, if you wish to. For instance, if you do not intend to build a transmitter yourself for the time being but would like to secure an operator license so that you can operate a friend's station, it may be obtained separately from the station authorization. Applicants for operator authorization have to pass a written examination of about fifty questions. Approximately two-thirds of the questions are on technical subjects; the remainder concern themselves with the United States radio laws and the amateur regulations. They are also required to demonstrate an ability to receive and transmit code at the rate of thirteen words per minute (five letters to the word). Applicants living within 125 miles airline of one of the examining centers designated by the Federal Communications Commission * have to appear in person at those cities for their examination, and have to pass the code test as given by the radio inspector. Those living more than 125 miles from one of these points are permitted to take the examination by mail and have the code test given them, under oath, by an already licensed operator.

The subject of preparing for the written examination is beyond the scope of this booklet. Although the examination deals with elementary radio, it is necessary to engage in some study for it. If you will carry out this study in conjunction with the constructing of your apparatus, you will find that your reading helps you to understand the operation of your sets and your construction of the equipment helps you to absorb the new knowledge. You are going to obtain an immense amount of enjoyment from amateur radio; it is well worth learning about. In the first place, if you do not possess a fair knowledge of elementary electricity, such as is taught in a high school physics course, we suggest that you obtain from your local library a good elementary electrical textbook. That is the groundwork for all radio theory. Then you should read a book that deals with radio itself in equally simple fashion, explaining elementary radio theory and the functioning of simple practical apparatus. Any satisfactory available text may be used, of course, but we would recommend that you obtain a copy of *The Radio Amateur's Handbook,* an American Radio Relay League publication which is a complete manual of amateur electrical and radio theory, construction and operation. While you will eventually find a personal copy of this book indispensable, you will probably be able to borrow a copy or find it at your local public library. It may be obtained from the League for $1.00, postpaid. ($1.50 outside U. S. A. proper.)

We also earnestly suggest that before going up for your test you obtain a copy of *The Radio Amateur's License Manual.* This booklet explains in detail the procedure in applying for licenses, lists many questions similar to those that will be asked in the examination and gives their correct answers, and includes the full text of the amateur regulations and pertinent portions of the radio law. The *Handbook* may be borrowed, but you should purchase a copy of the *License Manual,* for it is really indispensable to the new applicant. We very much wish that it were possible to publish the contents of that booklet in this one, but it is of equal size and it is not economically practicable to do so. The *License Manual* may be obtained for 25 cents, postpaid from the ARRL at West Hartford 7, Conn.

Practise sending, too, on your practice outfit, for in your code test you have to demonstrate ability both to send and receive at 13 w.p.m. You will undoubtedly find it a lot easier to send than to receive — everybody does. But don't try to hurry your sending. Grasp the key lightly but definitely with the thumb and first two or three fingers of the hand, and adjust the key so that there is an up-and-down motion of about one-sixteenth of an inch at the knob. Use a wrist motion. Learn to make the characters evenly and distinctly. *Don't* try to send fast. One of the surest indications of a beginner on the air is the fellow who tries to send rapidly and only makes an unintelligible mess of everything. It is a good idea to keep your sending speed on a level with your receiving speed.

There is nothing difficult about the examination for a person of average intelligence and application. Thousands of American amateurs between ten and sixty years of age have qualified. Your license, when you get it, will have a term of five years and, provided you show even a small amount of activity as an operator, may be renewed indefinitely without further examination of any kind.

* Atlanta, Ga.; Baltimore, Md.; Beaumont, Tex.; Birmingham, Ala.; Boston, Mass.; Buffalo, N. Y.; Charleston, W. Va.; Chicago, Ill.; Cincinnati, Cleveland, and Columbus, Ohio; Corpus Christi and Dallas, Tex.; Davenport, Ia.; Denver, Colo.; Des Moines, Ia.; Detroit, Mich.; Fort Wayne, Ind.; Fresno, Calif.; Galveston, Tex.; Grand Rapids, Mich.; Honolulu, T. H.; Indianapolis, Ind.; Kansas City, Mo.; Little Rock, Ark.; Los Angeles, Calif.; Memphis, Tenn.; Miami, Fla.; Milwaukee, Wis.; Nashville, Tenn.; New Orleans, La.; New York City; Norfolk, Va.; Oklahoma City, Okla.; Omaha, Nebr.; Philadelphia, and Pittsburgh, Pa.; Portland, Ore.; St. Louis, Mo.; St. Paul, Minn.; Salt Lake City, Utah; San Antonio, Tex.; San Francisco, Calif.; Savannah, Ga.; Schenectady, N. Y.; Seattle, Wash.; Sioux Falls, S. D.; Syracuse, N. Y.; Tampa, Fla.; Tulsa, Okla.; Washington, D. C.; Williamsport, Pa.; Winston-Salem, N. C.

## GETTING ON THE AIR

And now, after you have built your receiver and transmitter and put them in operating condition, have obtained your licenses, and have learned something of the customs and practices of operating, you are ready to take your final step — the step for which you have worked through all these weeks — your first actual operation on the air as an amateur.

You sit down some evening before your receiver and light up the tubes. Tuning in on the 3500-kc. band, let us say, you hear some station (not too far away!) sending a "CQ" and finally signing his own call. You turn on your transmitter, and call that station — just a bit shakily, no doubt. After making a reasonably long call, you sign off and listen for him again. Perhaps he does not come back. Too bad! — but don't be discouraged. While it has happened that amateurs have worked the first station they ever called, this experience is not the rule. Try again. Perhaps you will still fail to "connect," and you may call all that evening without working anybody.

But you keep on trying the next night, and soon there comes a time when you enjoy that never-to-be-forgotten thrill of hearing the other fellow call your station. And then you talk with him, learn where he is, and hear him tell you how good your signal is at his "shack" and perhaps make a schedule to call him again the next night for another talk. So you start to learn the thrill and pleasure that come from talking to another fellow-being hundreds (even thousands) of miles away, from the privacy of your own home, and with apparatus that you have constructed with your own hands. It is a thrill that never wears off.

It is probable that one of the first things you will be asked, when you begin working other amateurs, is to "Psc QSL OM." What the other fellow is referring to is a custom that has grown to be a part of amateur radio, known as the exchanging of QSL (acknowledgment) cards. Most amateurs have postcards printed up with their call prominently displayed, and other data on their station, leaving space of course to put the call of the amateur to whom they are going to send the card. When you work some distant amateur, he may ask you (or you may ask him) to exchange cards, as noted above. You then make out one of your cards, address it to him, and mail it, usually receiving one of his in return. Many amateurs have the walls of their operating room literally plastered with QSL cards from all over the world.

Oh yes — don't forget to keep a log of your station operation. For one thing, the United States amateur regulations require you to do this, but aside from that every worthwhile amateur keeps a neat log as a matter of pride. Your log should record all calls made by the transmitter, calls of stations worked, time, frequency band and power of your transmitter, and the name of the operator.

You are now a full-fledged amateur, and ready to take your place in the amateur ranks. Do not try to hurry matters in building your station or operating it. Be a gentleman on the air and don't be afraid to admit that you are a beginner. If someone sends too fast for you, tell him so — don't give some lame excuse such as "QRM" or "QRN" for having missed some of his remarks. A genial request to send slower will practically always get the desired result, and those you are working will think more of you for it.

The American Radio Relay League, at West Hartford 7, Conn., which publishes this pamphlet, is a society of and for amateurs, and it will be more than glad to help you out with your problems. It may be that, later, you will wish to become a member of the League. Most amateurs are members. Station ownership is not necessary to membership — you have only to be interested in amateur radio. Dues are $2.50 a year (foreign $3.00) and include a year's subscription to the monthly magazine *QST*, often referred to as the "amateur's bible." Every amateur reads *QST*; each month's issue is filled with information on the latest types of receivers and transmitters, and news from all over the country. If you cannot obtain it from your newsstand, a sample copy may be obtained for 25 cents from the ARRL.

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James E. Lewis 112 YF 54
R. D. 1
New Kensington, Penna.

## THE "Q" CODE

As explained in the text of this booklet, this is a very useful internationally-agreed code designed to meet major needs in international radio communication. There are several times as many "Q" signals as those we list here, but those omitted bear primarily upon commercial radio and have little application in amateur contacts. The abbreviations themselves have the meanings shown in the "Answer" column. When an abbreviation is followed by the signal for an interrogation mark (• • ▬ ▬ • •) it assumes the meaning shown in the "Question" column.

| *Abbreviation* | *Question* | *Answer* |
|---|---|---|
| QRG | Will you tell me my exact frequency (wavelength) in kc/s (or m)? | Your exact frequency (wavelength) is ........ kc/s (or ........ m). |
| QRI | Is my note good? | Your note varies. |
| QRJ | Are you receiving me badly? Are my signals weak? | I can not receive you. Your signals are too weak. |
| QRK | What is the readability of my signals (1 to 5)? | The readability of your signals is...... (1 to 5). |
| QRL | Are you busy? | I am busy. Or (I am busy with ......). Please do not interfere. |
| QRM | Are you being interfered with? | I am being interfered with. |
| QRN | Are you troubled by atmospherics? | I am troubled by atmospherics. |
| QRO | Shall I increase power? | Increase power. |
| QRP | Shall I decrease power? | Decrease power. |
| QRQ | Shall I send faster? | Send faster (...... words per minute). |
| QRS | Shall I send more slowly? | Send more slowly (........ words per minute). |
| QRT | Shall I stop sending? | Stop sending. |
| QRU | Have you anything for me? | I have nothing for you. |
| QRV | Are you ready? | I am ready. |
| QRX | Shall I wait? When will you call me again? | Wait until I have finished communicating with........ I will call you immediately (or at ........ o'clock). |
| QRZ | By whom am I being called? | You are being called by ........ |
| QSA | What is the strength of my signals (1 to 5)? | The strength of your signals is ........ (1 to 5). |
| QSB | Does the strength of my signals vary? | The strength of your signals varies. |
| QSK | Shall I continue with the transmission of all my traffic; I can hear you through my signals? | Continue with the transmission of all your traffic, I will interrupt you if necessary. |
| QSL | Can you give me acknowledgment of receipt? | I give you acknowledgment of receipt. |
| QSO | Can you communicate with .......... directly (or through the intermediary of ........)? | I can communicate with ........ directly (or through the intermediary of ........). |
| QSP | Will you relay to ........ free of charge? | I will relay to ........ free of charge. |
| QSY | Shall I send on .... kc/s (or .... m) without changing the type of wave? | Send on .... kc/s (or .... m) without changing the type of wave. |
| QSZ | Shall I send each word or group twice? | Send each word or group twice. |
| QTA | Shall I cancel telegram No. .... as if it had not been sent? | Cancel telegram No. ...... as if it had not been sent. |
| QTC | How many telegrams have you to send? | I have .... telegrams for you or for .... |
| QTH | What is your location? | My location is ........ |

## REQUEST COUPON

*American Radio Relay League*
*West Hartford 7, Conn.*

*Date*....................

GENTLEMEN:

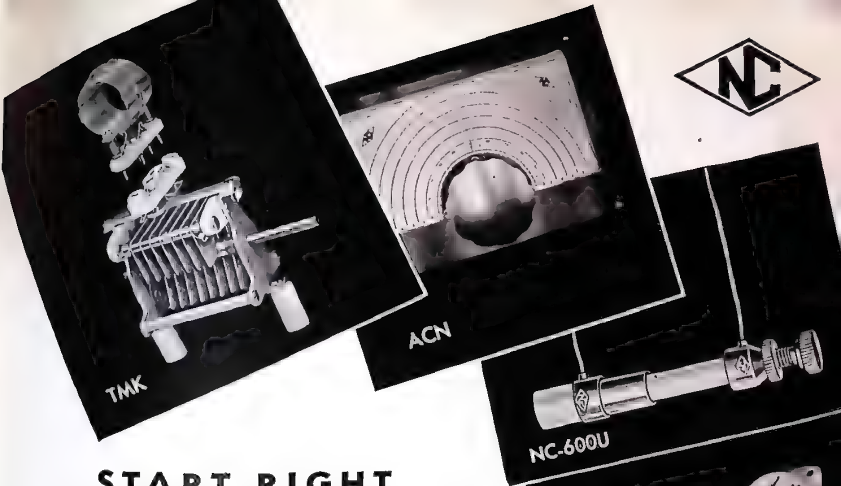
I am interested in amateur radio. Please send me information about the American Radio Relay League. (If sample copy of latest issue of *QST* is desired, check here ☐ and enclose 25c — no stamps.)

*Name* ........................................................................

*Street or box address* ........................................................

*City and State* ...............................................................

*Please write your name and address plainly*

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**NEUTRALIZING CONDENSER** ▪ The NC-600U Neutralizing condenser is for low power beam tubes such as the 6L6 requiring from .5 to 4 mmf and 1500 peak volts. Other larger neutralizing condensers are available for every type of tube.

**SOCKETS** ▪ National makes a complete line of sockets. Illustrated at the right are the CIR-6 for receiving tubes; the XM-50, a husky metal-shell socket for tubes having the Jumbo 4-pin base and lastly, the HX-100S, a big low-loss wafer socket for the Eimac 4-125-A, 4-250-A and other tubes using the Giant 5-pin base.

**CHOKES** ▪ The R-100U Choke illustrated at the right is easy to mount and electrically correct. It is ideal for low power circuits at amateur frequencies. The R-152 is a bigger choke for heavy duty transmitter use on the 80 and 160 meter bands. The R-175 is a type of RF Choke that is suitable for either parallel or series feed in transmitters of up to 3000 volts modulated plate supply. For all amateur bands up to 28 MC.

**COILS** ▪ High frequency coils for the microwaves. AR-2 and AR-5 together cover the range from 37 to 220 Mc. Type XR-50 is a blank form to wind as desired. All are high-Q units, featuring adjustable inductance and all are compact and convenient to mount.



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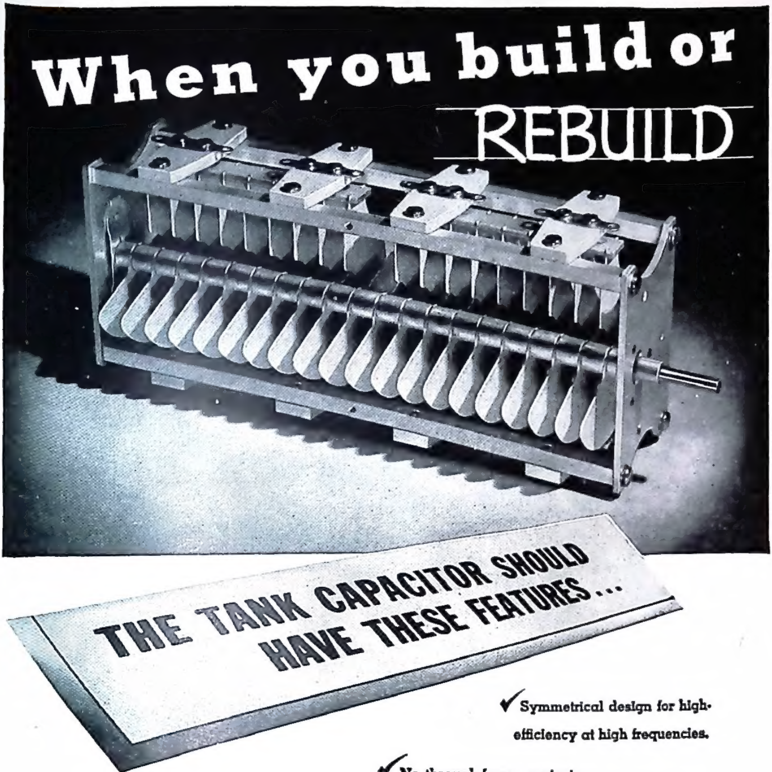


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